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AGATHON ALLOY STEELS

METAL PROGRESS

Table of contents

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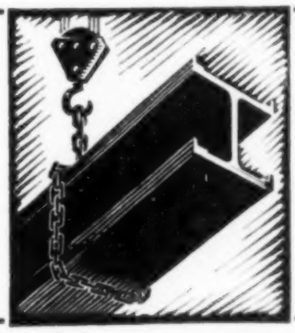

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Ernest E. Thum, Editor.

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METALLURGICAL INVESTIGATIONS AT BELL LABORATORIES

When a research laboratory has 6,000 persons on its payroll and spends $21,000,000 a year, it is no longer one of those sheltered nooks, but has become a big business. This should be taken in no disparaging sense, for even among the intense activities of Bell Telephone Laboratories may be found some sheltered nooks where the genius of a single scientist is afforded facilities to carry out his ideas. But most of the work is consciously directed toward developing and perfecting the art of transmitting intelligence electrically. Efforts of so many trained workers, even in this wide field, must be pointed toward particular objectives by proper organization of the work — an organization sufficiently precise to prevent waste effort, yet sufficiently flexible to adapt itself to the changes forecast by new discoveries, by new demands of the public, or by predictable economic trends.

It is one of the consequences of this careful organization of effort that a visitor at Bell Telephone Laboratories in New York finds no separately constituted metallurgical department. Much fundamental study on metals has been and is being done; an enormous mass of data on the properties of metals and alloys has been and is being accumulated; but this is an incidental activity of a great organization whose main objective is telephonic communication, and which, naturally, is interested in metals only as they contribute to this main objective.

In other words, the specific tasks are to create new and better types of telephonic apparatus and to perfect the systems whereby these serve the public. Study of individual pieces of apparatus involves the scrutiny of the substances which are used in their manufacture: Metals, alloys, minerals, plastics, fabrics. Study of commercial metals for apparatus is a branch of this, and is concentrated under John R. Townsend, Mem. A.S.S.T., in one section of the "Apparatus Development Department." In the event that no commercial metal or alloy can be found suitable for the service demanded by the designing engineer, then the problem is turned over to the "Research Department," which in its chemical division has a well-equipped section directed by J. E. Harris, Mem. A.S.S.T., devoted to fundamental researches in the metallurgy of base and precious metals.

Looked at from this angle (and it is only one way to view such an organization as the Bell Telephone Laboratories), the work on metals is quite utilitarian. Questions which are being asked of Mr. Townsend are: "How much load can we place on this piece of spring brass?" and the answer requires extensive fatigue tests on the alloy; "What is the best sheet to use for sockets for switchboard lamps?" and many tests on contact resistance of materials under

Men Make Laboratories
At top of page is J. R. Townsend of the Apparatus Development Department. Below is J. E. Harris, Research Metallurgist

accelerated atmospheric corrosion must be made; "How much internal air pressure can a lead-sheathed cable hold?" and the answer requires knowledge of the limiting creep values of lead and its hardened alloys, and some intensive studies of solders and methods of making sound wiped joints!

If, on the other hand, a new vacuum tube requires a filament of such characteristics that no known metal can fill the demand, Mr. Harris's men start searching out new alloys, or modifications in composition or manufacturing technique of older ones. A new solder containing lead, tin and cadmium was, for instance, discovered and developed in connection with the recent investigations on hardened lead for cable sheath. It has the advantage of having a wider mushy range than the ordinary lead-tin solder and solidifying with a finer crystalline grain. It can therefore be more easily made into a wiped joint, and the joint can be airtight. At the time it was developed, the new solder was cheaper than the old, but the price is naturally dependent upon the changeable ratio of costs of the component metals.

Brief mention of these current metallurgical activities in the laboratories cannot include even the briefest list of many notable accomplishments in the past. The best known of these discoveries are probably permalloy (nickel-iron) and perminvar (cobalt-nickel-iron). Furthermore, they represent best the type of metallurgical research work which is being done to supply a need not satisfied by any commercial material. Consequently an outline of the work will be given.

Prior to 1913, when Gustaf W. Elmen and his associates in the magnetic section of Bell Telephone Laboratories turned their attention to the problem, it was commonly assumed that Norway iron (made in U.S.A.!) and silicon steel represented the best possible materials for transformer cores. Their magnetic properties were thought to be as good as could be got, just as at present pure copper is thought to be the ultimate for electrical conductivity. The requirements of a telephonic circuit, with its infinitesimal currents, are quite different from those of power transformers, however. A re-examination of the high nickel-iron alloys showed they had unusual properties never before suspected

because they had never been tested under the particular conditions set up by currents as low as one ten-millionth ampere.

It will be impossible to give even the shortest outline of the work which led to the discovery of the best alloying proportions, melting practice, fabrication routine, and heat treatment of these special magnetic alloys. The problem was complicated by the fact that for some purposes, such as cores for loading coils, an aggregate of finely powdered permalloy is desirable, and therefore an alloy must be cast brittle enough so it can be ground to 120 mesh; while for other purposes, such as submarine cable windings, a ductile permalloy is necessary, capable of being rolled into thin ribbon. To make the problem harder, both ductile and brittle permalloys must have the same magnetic characteristics; namely, highest initial permeability, smallest coercive force, and lowest hysteresis — in other words, its magnetism must keep in step with the smallest change in the inducing current, meanwhile absorbing and wasting only the minimum of energy.

Suffice it to say that the problem was eventually solved and the alloys have been used extensively for the last ten years. However, the search for perfection still goes on. During a recent visit to the laboratory, production of permalloy was going on at a semi-commercial scale to discover the cause of certain irregularities cropping up in routine manufacture at Western Electric Co., the manufacturing subsidiary of the Bell System. For such investigations, and to work out successful manufacturing technique before turning a new alloy into production, the research metallurgists have a full equipment of melting furnaces, heating and annealing furnaces, and mill equipment, such as extrusion press, swaging machines, stand of rolls, and wire drawing equipment.

Indeed, it commonly happens that considerable amounts of a new metallic alloy are fabricated in the research laboratory before its commercial production begins elsewhere. At the present time are being manufactured ribbons of platinum alloy, the cores for activated filaments in the vacuum tubes for repeaters used by the long lines department. By proper attention to operating detail the life of these metallic elements has been increased to 50,000

G. W. Elmen, Magnetic Research Engineer, Supervising an Experimental Melt of Permalloy, a Highly Magnetic Material Developed at Bell Laboratories. This material has multiplied by several times the number of messages that can be sent over a single conductor

hr. in place of 1,500. This improvement has required highly purified metals, melted and cast in a vacuum. The latter detail is accomplished in the equipment shown in the figure, wherein a closed L-shaped quartz tube contains a crucible in one branch and a mold in the other. It is connected to a vacuum pump after the charge is placed within the coil of an induction furnace. When the metal is melted, furnace and quartz tube are tilted 90° (note the hinges on the feet of the upper table) and the metal runs from the crucible into the mold and there solidifies into a sound ingot.

It is suspected that traces of gas in various common metals and alloys have a disproportionate effect on the electrical and magnetic properties, so a research on this problem is now under way wherein gases will be evacuated from the molten material at pressures as low as 1/100,000 mm. of mercury (1/76,000,000 of an atmosphere). This is about 1/100 the pressure used by most investigators of this question, and is achieved by the sole use of glass and metal tube, welded together, in place of the conventional rubber hose and ground-glass joints. Analysis of the gases evolved from the metal will be made in a closed system; some compounds will be absorbed and the added weight noted by the extension of a calibrated quartz spring; others will be determined by the change in vapor pressure as they are frozen out at liquid-air temperatures.

This all-too-brief account must now devote some attention to the activities of the metallurgists in the Apparatus Development Department. As mentioned at the beginning of the article, their activities are largely devoted to a study of the properties of commercial metals and alloys. Consequently, the laboratories have a great deal of standardized equipment similar to that found in many other modern testing laboratories.

An important by-product of the great amount of testing always going on is the development of numerous improvements to standard testing equipment, or the adaptation of ordinary technique to a specialized problem. This is well exemplified in the fatigue testing laboratory. Equipment here, when running at capacity, will be working on no less than 220 test specimens — probably the largest battery in existence. Power for constant-speed motors is secured from a direct current main leading straight from the substation. This is converted by a motor-generator set to alternating current for the driving motors.

Many metals used in telephonic apparatus are subject to cyclic stresses, and are liable to fatigue failure. Considerable testing is therefore conducted to determine how great a periodic load can be imposed on the metal in question. Much of the apparatus used for these tests was developed in the laboratories. For example, one machine has been developed for testing sheet spring material. For the tests, the metal is cut into narrow strips, one end of which is held fast during the test, while the other end is gripped by an arm moving rapidly back and forth. Three of these machines are in service, each capable of testing 28 samples at one time.

High Frequency Induction Furnace Enables Metal To Be Melted and Cast in a Vacuum. Observer looks into furnace through a transparent quartz window, and when time is right, tilts entire equipment so metal runs into a mold contained in horizontal leg

Other machines have been developed in which the stresses are applied by rotating cam shafts, the samples being pressed against the cam by springs. Three 28-specimen machines of this type are in service and are used for testing soft metals, such as cable sheath alloys. Two McAdam type testing machines are also used. Each of these machines has eight rotating heads carrying cantilever test bars. Weights applied to these bars produce a periodic change from tension to compression as the bar rotates. In practice, tests are made on eight to forty identical samples at a time. The results from the entire bank are then plotted to give a value for the endurance limit within the desired degree of accuracy.

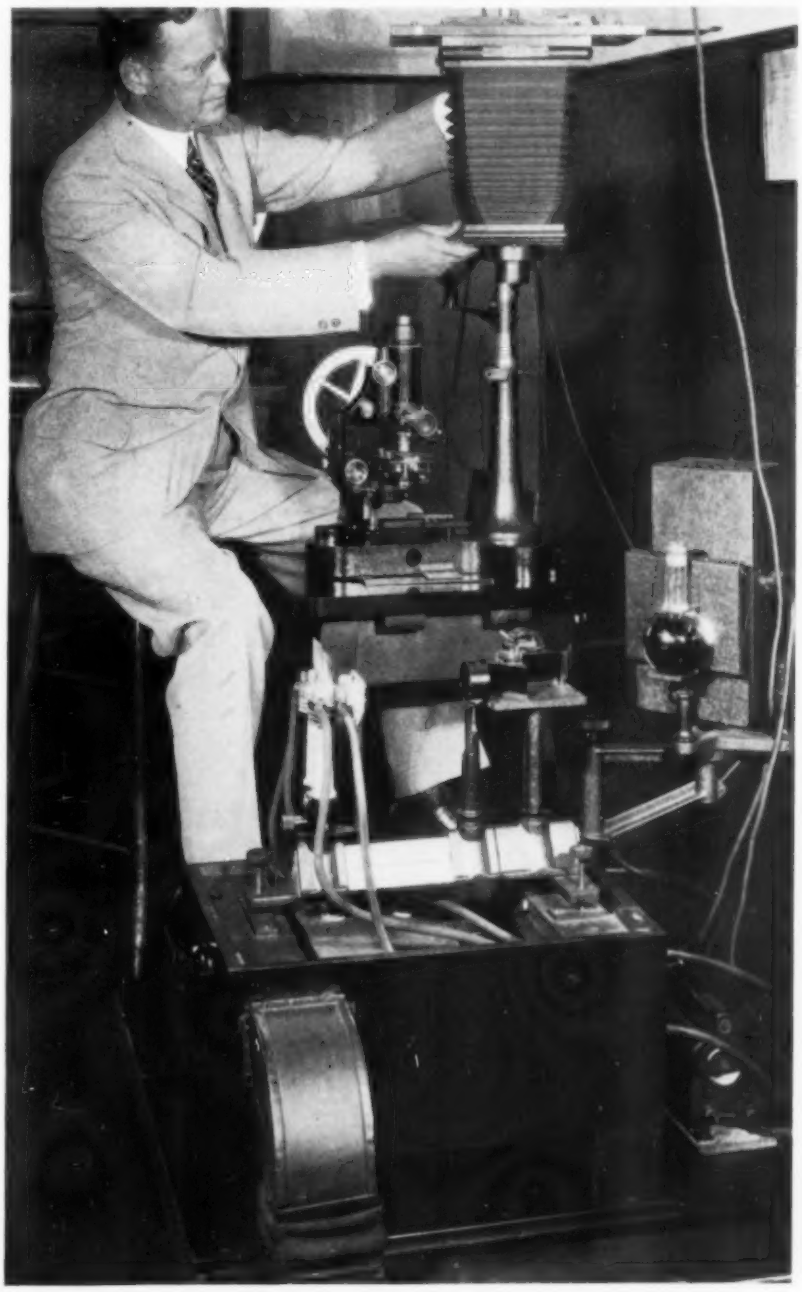
It is only natural that much attention should be given to short-time tests for the endurance limit.

Just at present an adaptation of the Moore-Konzo test is being studied in an attempt to correlate the stress-electrical resistance curve to the long-time fatigue data for copper, steel, aluminum and cable sheath alloys of lead.

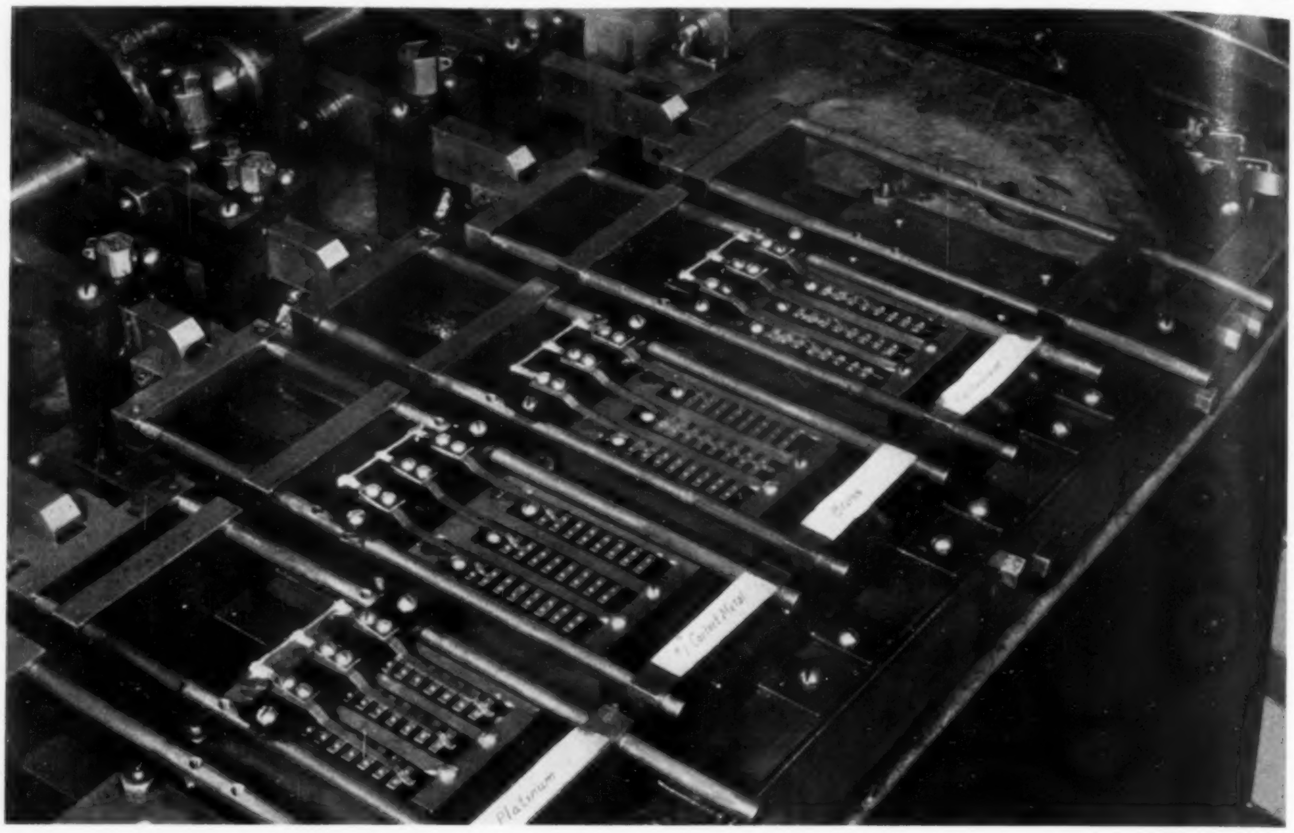
Another interesting special machine for studying useful properties of metal is a bending test for sheet metal, wherein a ½-in. strip is fixed at one end between vise jaws, the top corners of which are rounded to a radius 8 times the thickness of the sheet. An oscillating arm then bends the strip sharply 90°, first to right and then to left. The number of bends to break is regarded as a most useful measure of toughness and workability of sheet metal (and wire), being more sensitive than the tensile strength, elongation, or the Erichsen cupping test.

Development of automatic switching equipment for dial-operated telephones has involved many studies on specific properties of various alloys. Only one can be mentioned here — the determination of the contact resistance of various sheet metals.

Enough work has been done on this problem to indicate that contact resistivity is not a specific property of the two materials in wiping contact. It also varies with the amount and nature of the corrosion product. Furthermore,



F. F. Lucas, Chief Microscopist of Bell Telephone Laboratories, Adjusting the Ultra-Violet Microscope, the Technique of Which He Brought to a High State of Perfection



Wear Test Machine. Mechanical arms cause these contacts to slide back and forward over other surfaces under examination, and the electrical resistance of the contact measured at stated intervals. Such tests are necessary to determine the best materials for many parts of switchboard apparatus in both manual and dial system

the rate of corrosion in an industrial atmosphere is increased by rubbing the parts together. For these reasons the test method is to mount a large number of samples (duplicates of the parts used in the switchboards) and operate them in definite cycles of action and rest in a humid atmosphere containing 1,000 times normal amounts of sulphur and carbon dioxide. Periodic measurements of the resistance across all joints are made; 100 observations of supposed identical conditions are made and interpreted by statistical methods to give the figure for the most likely result.

Precision Measurements

For high precision measurements, extremely accurate apparatus is available. In one room can be seen apparatus designed for measuring to a hundred-thousandth of an inch. Here are an end measuring machine and a star comparator from the Société Genevoise; a Zeiss optimeter; a super-micrometer; a line comparator (with a standard yard calibrated by the Bureau of Standards). In an adjoining room can be found a "profile lathe" in which a carefully chosen lens system projects on a distant wall a highly magnified shadow of the piece of metal under examination. Photographs of these shadows permit extremely rapid measurements of contours to an accuracy of a thousandth of an inch. For such fine measurements as the expansion with rising temperature of a small piece of metal, there is an interferometer using light rays to measure to an accuracy of a ten-millionth of an inch.

In closing, it may be noted that an extremely interesting feature of the testing work are the many attachments developed by members of the Bell Laboratories staff, adapting some telephonic principle, radio tube or modern electrical device to more conventional apparatus, to make it more responsive to the operator's desire.

SEAMLESS STEEL TUBING MADE IN . . . LARGE SIZES

By G. P. McNiff
Assistant Vice President
National Tube Co.

A Paper Read at Western Metal Congress

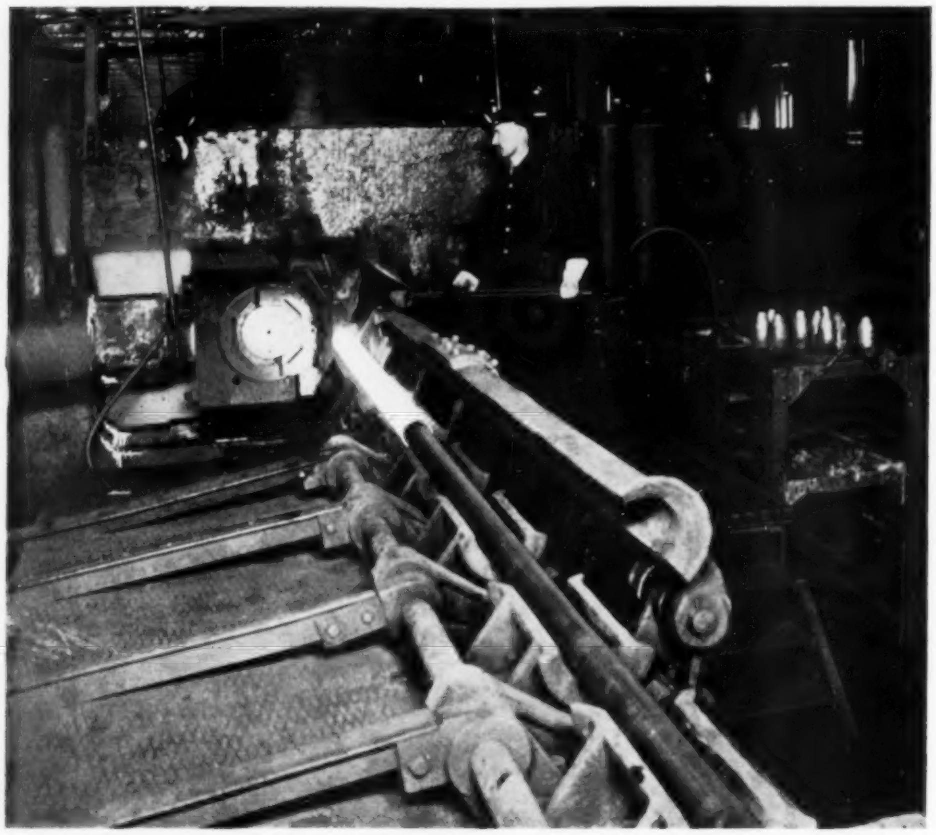
PROBABLY less is known about the methods of producing seamless tubing than of any of the common processes of rolling steel. It is only recently that this unique and interesting process has been recognized as one of the more important of the many processes for finishing steel. It had its inception in the invention of the so-called piercing mill, by the Mannesmann brothers, in Germany about 1885.

Quite a number of the years intervening between the invention of the piercing mill and the present day were lost, so far as the development of the seamless process was concerned, because the lap- and butt-weld tubes then being produced met the requirements of the day. Apparently there was no need for stronger and otherwise better tubes. About 1895 (near the date of the invention by R. C. Stiefel of the disc piercing mill) a demand was evident from bicycle manufacturers for a tube of better quality than that produced by either of the older processes, and it was this impetus that really brought about the first development of any consequence in seamless tubing. This market was short lived, however, and the product expensive.

With the decline of the demand for bicycle tubing it became evident that if the process was to survive, further developments and improvements would be necessary. While these were somewhat slow, nevertheless they have been steady, and today the seamless process of making tubes is displacing, in the modern steel plants, the old lap-weld process — thus enabling manufacturers to meet the demands of the trade for a tube of both quality and properties far beyond those heretofore available.

Present day high pressure power plants, oil refineries and gas lines owe much to the seamless process, which has now emerged from the apparent obscurity surrounding the early years to its present high state of development. It is only fair to state that National Tube Co. has pioneered in this work and is largely responsible for the improvements made, and is today the largest manufacturer of this class of product in the United States.

For the production of pipe and tubing up to $6\frac{5}{8}$ in. outside diameter, both the Stiefel and Mannesmann piercing mills are being used. In this range of pipe sizes, all piercing is done by one mill, but on larger sizes two piercing mills are used, one to produce a short heavy-wall billet, and the second to expand, elongate and reduce the wall thickness. This latter method,



Billet Emerging From Piercing Mill. Workman stands ready with mandrel ready to attach to water-cooled rod before arrival of next billet

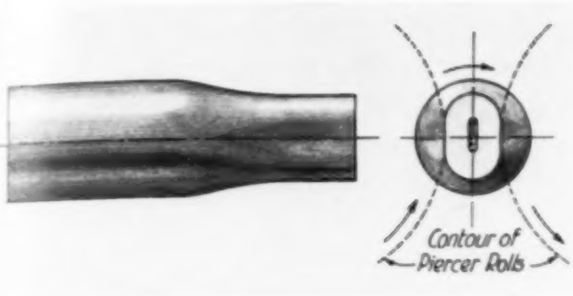
called "double piercing," is distinctly a National Tube Co. development, and paved the way for the manufacture of sizes larger than had been thought possible prior to its development.

Whether a tube has been single pierced by the Stiefel or Mannesmann process, or double pierced by the National Tube Co. process, the next step is to pass the hollow billet through a two high or plug rolling mill, where it is reduced in diameter and wall thickness. After this comes the reeling operation and then sizing, all of which will be taken up in order and described later, after a brief description of the theory of piercing.

Unique Machine for Piercing

The Mannesmann machine for piercing round billets embodies the principle of diagonal rolling, which at the time of its inception proved to be a startling innovation. This principle can be carried out in a number of different ways with rolls of different shapes, but only the manner in which it is employed at the present time will be described.

The rolls used in this machine are comparatively heavy. They measure about 36 in. over-all, and, in the body, or face, 24 in. in length, and from 32 to 40 in. in diameter. These dimensions are varied according to the size of tubes to be made. Their shape, as shown in the sketch, resembles that of a piece cut from the middle of a very large spindle with a flat portion about one inch long at the middle. From this flat part each roll tapers toward each end at an angle of 5 to 10°. This angularity of the rolls is necessary to produce the play of forces required to effect the piercing and at the same time permit the billet to be drawn continuously through the mill. These rolls may be made of steel or other suitable material, and are made with a neck for bearings like an ordinary roll, but are connected with the power by a type of universal joint instead of wobblers. When they are placed in their housings, they lie side by side instead of one above the other, and their axes are inclined in opposite directions, each at an angle of 6 to 12° with the line of advance of the billet, so that the rolls cross each other at their centers. Upon the amount of this angle de-



Piercing Mill Rolls Open Central Cavity by Rapid Alternations of Pressure From Opposite Sides. Surface metal is drawn ahead in a spiral, and metal is drawn from center over the mandrel

pends the speed with which the billet will be drawn through the mill. They can be adjusted laterally in their housings, and are set so that the distance between their rolling surfaces at the middle is a definite amount less than the diameter of the billet to be pierced.

Although the action of the rolls is far from being simple, the piercing is performed apparently with as much ease as any ordinary rolling process. A round billet of the proper length and diameter to make the size and length of tube desired is first centered on one end to a depth of about one inch, and then heated uniformly to the usual temperatures for rolling light sections. Next, a mandrel, or plug, with a pointed nose, tapered at the proper angle and known as the piercer point, is attached to a water cooled rod designed for the purpose, and inserted between the rolls from the delivery side, so that its pointed end just passes the line where the rolls cross.

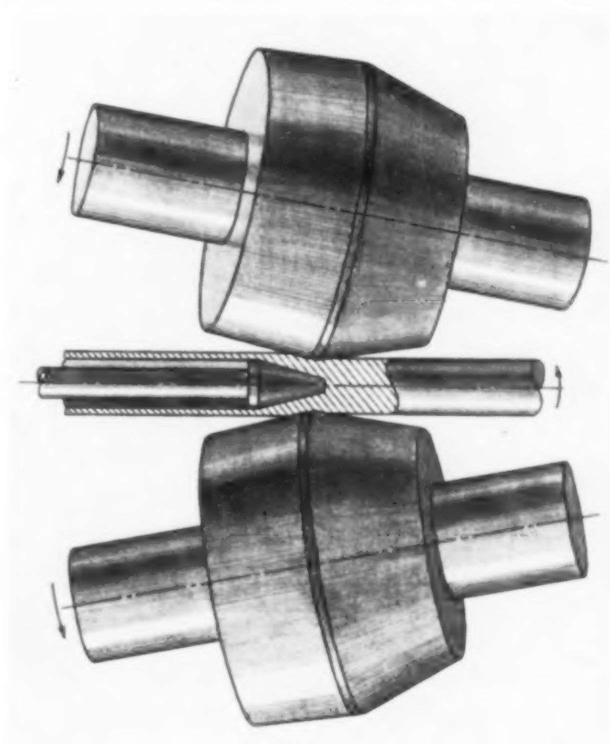
With the rolls revolving at a constant speed, the heated billet, lying in a trough, is now pushed (centered end first) into the space between the rolls. This first push is by means of a rod actuated by a hydraulic or compressed air cylinder. The rolls immediately grasp the billet, revolve it rapidly, and pull it slowly forward. At the same time they draw the metal away from the center to form a hole, they elongate and enlarge this hole, and force the metal over the plug. This plug and its supporting rod revolve in a thrust bearing at the same rate as the billet, yet they maintain the same relative position with respect to the rolls. Less than a minute is required to perform this composite operation.

When the billet issues from the mill, having been forced entirely over the mandrel or plug, it is in the form of a thick walled tube, somewhat rough on its surface but fairly uniform as to thickness of wall.

Hole Formed by Outside Pressure

The action of the rolls is somewhat difficult to understand and still more difficult to explain satisfactorily. It is evident that the forward motion of the billet is caused by the inclination of the axes of the rolls. It is not so readily understood how these two rolls, by exerting pressure only on the surface of the billet, are able to force the metal over the mandrel to form a tube from a solid billet. It is to be especially noted that the mandrel is not forced *through* the metal, but that the rolls cause the metal to flow *over* and about the mandrel. To bring

Rolls for Mannesmann Piercing Mill Are Short and Have Axes Mounted at Slight Angle to Line of Advance of Billet. Rotation in the directions indicated spins the billet and works the surface layers over the mandrel in a spiral path



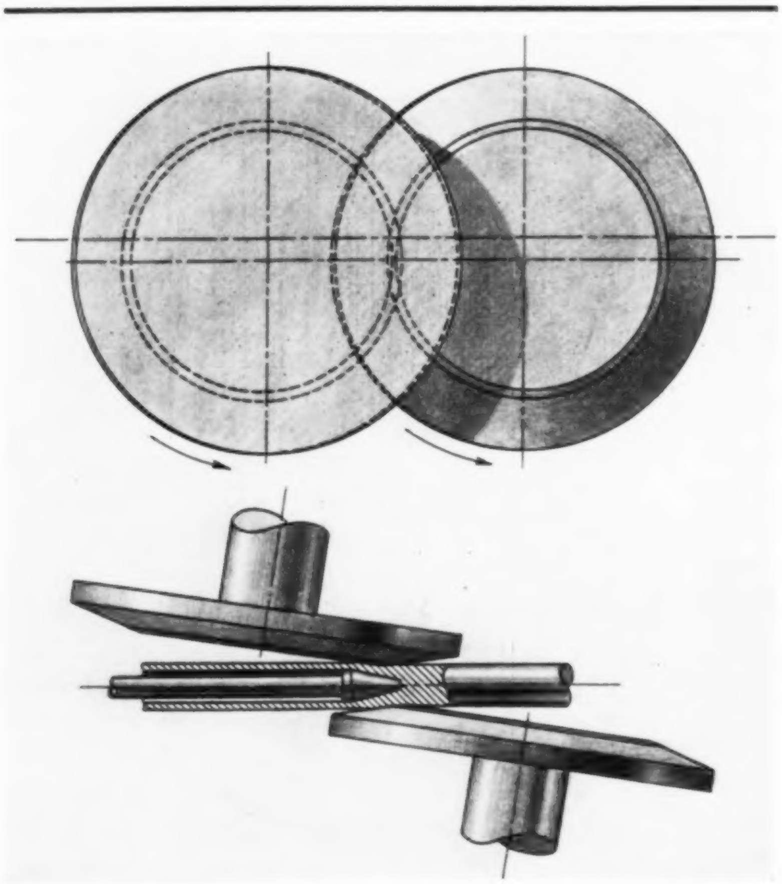
about this result, the rolls must first draw metal away from the center of the billet, which action tends to form a central hole or cavity, for the passage of the mandrel or piercer. This is evident from the fact that a small, but somewhat irregular, hole may be formed in a billet without the use of the piercer point. Indeed, such a hole can even be opened in the center of any solid cylindrically-shaped plastic body by rolling it between two flat surfaces!

Steel workers, particularly hammermen, are familiar with the fact that if a piece of steel in the form of a round be pressed or hammered into an oval form, several times in succession, a rupture will occur in the center that will extend longitudinally through the middle of the bar. This is due to the fact that when pressure is applied to the round bar at diametrically opposite points sufficient to make one diameter shorter and that at right angles longer, the spreading metal (which takes place along the long diameter and in opposite directions) sets up a lateral tension that may cause its particles to be drawn away from the center of the bar. This is the action that first occurs in the roll-piercing machine.

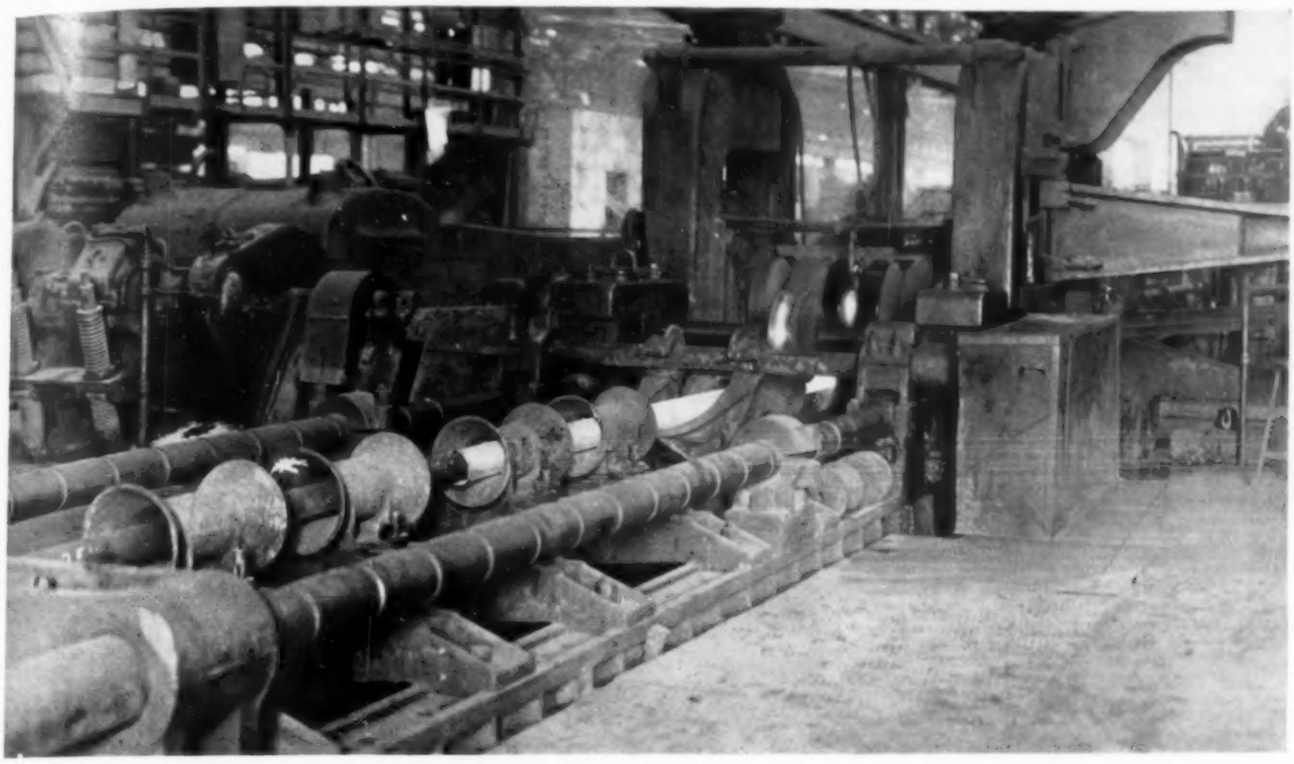
The action may be visualized with the aid of the sketch at top page 41. As the billet, which is in a plastic state, enters the mill, the rolls grasp it at diametrically opposite points on its circumference while it is yet about 4 in. from their centers. As they draw the billet forward they continue to compress it at these opposite points, and since they revolve it rapidly, these points are continually changing. In this way a small hole is quickly formed and is then rapidly enlarged.

This enlargement is due to two things. As the rolls are larger at their centers than at the region where they grasp the billet, the increasing peripheral speed tends to produce a twisting action on the outer surface of the billet which is gripped between the rolls. As their axes are inclined to the axis of the billet, they at the same time exert a forward pull upon the outer surface of the billet. The result of this double action is that the metal is forced to flow in a spiral path, and since the decrease in the diameter of the bar is not sufficient to compensate for the increase in length, metal must be withdrawn from the center to compensate for the deficiency. The central opening is further enlarged by the rolling-on process that occurs as the hollow part of the billet is forced over the mandrel. Rolling-on increases the diameter, hence decreases the thickness of the wall.

As pointed out in a former paragraph, it is the practice to place the piercer point a little beyond the centers of the rolls. This position is necessary in order that the billet may be forced entirely over the mandrel before the rolls lose their grip. Otherwise the



Stiefel Machine Has Two Discs, of Properly Contoured Surface, for Gripping the Billet to be Pierced. Essentially the action is the same as in the Mannesmann mill



Rear Side of Plug Mill. A pierced billet is rolled over a mandrel by the two-high rolls, the upper roll raised and the tube returned to the front end by the smaller stripper rolls. Several such passes in succession fix the wall thickness

piercer point would remain imbedded in the metai. Consequently the piercer point is placed so it probably does some work, but the action of the rolls is the main force in pulling the metal away from the center.

Since the mandrel cannot be held to an exact center at the start, and it is desirable to roll-on before the central opening is very large, the forward end of the billet is centered to insure that the point of the mandrel will penetrate the billet at or very near its axis. At the end of the rolling, the mandrel bar is backed out of the tube which encircles it, and the mandrel, which drops from its end, is plunged into water to cool. The process can then be immediately repeated by placing another cold mandrel on the bar as before.

Advantages of Stiefel Machine

The actuating surfaces in the Stiefel machine, which are two in number and of the same shape, have the form of large discs about 30 in. diameter. The rolling faces of these discs are bevelled at an angle of about $7\frac{1}{2}°$ for a distance from the edge equal to nearly half the radius. These two discs are mounted on the ends of two parallel shafts that extend from two points in opposite directions. The distance between the centers of the shafts, produced, is about two-thirds the diameter of the discs.

From this arrangement, sketched on the left, only sections of the two discs face each other, corresponding to a little less than one-third of their diameters. These sections are the working surfaces, and are separated by a space slightly less than the diameter of the billet to be pierced. Each shaft is connected through gears to a main driving shaft and both discs are revolved in the same direction and at the same rate. Between the discs and extending beyond the mill on both sides is a trough for supporting the billet during the piercing process. This trough is fixed in a position to cause the billet to enter the mill between the discs on a level a little below their centers of rotation and along a line which is slightly inclined to the base plane of each.

Like the Mannesmann machine, the opera-

Final Operations Are Done on a Sinking Mill, a Continuous Mill With Roll-Axes at 90° to Pass on Either Side. Photos on this and next page courtesy Aetna-Standard Engineering Company

tion of the Stiefel mill is very simple. The billet, which has been previously centered, is heated to a uniform forging temperature, the plug, or mandrel, supported on the end of a bar is put in position between the discs from the delivery side, and the billet is shoved into the mill from the opposite side by means of a mechanical pusher. The discs then grip the billet, revolve it rapidly, pull it forward, draw out the metal to make a hole in the center, and force over the mandrel the wall of the rough tube thus formed.

Manufacture of Large Sizes

It is evident that the steel is subjected to considerable distortion in both these processes, and only billets of the best steel, absolutely sound and of uniform material, and heated to a uniform temperature throughout, can be used. With such material, these mills pierce billets as accurately as can be done by any other commercial method.

Neither method, however, permits of the speed of production desirable on larger sizes. It is to be especially noted that the amount of metal displaced increases considerably as the size is increased. This deficiency led the National Tube Co. to the development of the double piercing process in 1921.

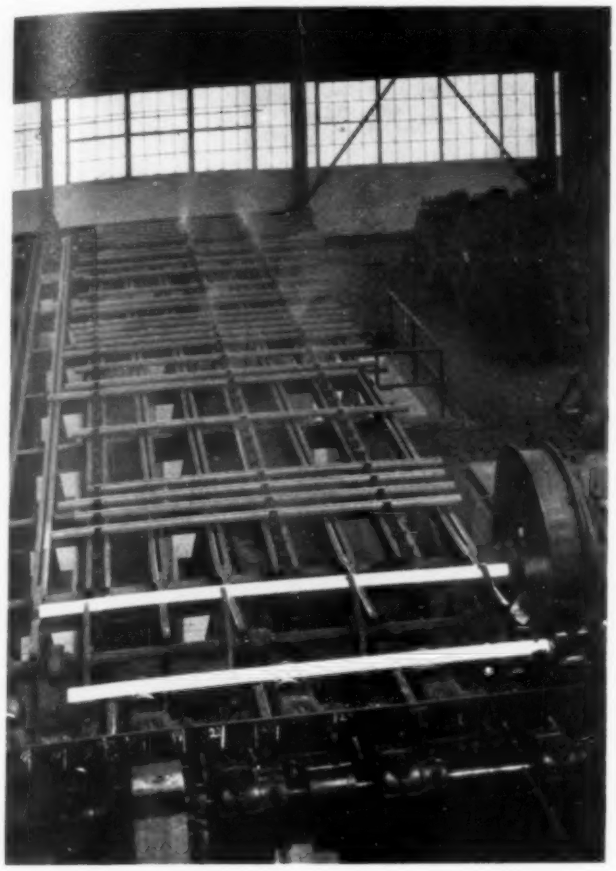
This improvement consists essentially of a second piercing operation on the already hollow billet. The advantages are at once obvious. Instead of it being necessary to displace in one operation a large quantity of metal at a slow rate of speed, a small quantity can be displaced quite rapidly in the first operation, and later expanded with the same rapidity to the size necessary for subsequent processing.

Some idea of the advantages can be gained from a comparison of piercing practice by the single and double methods for producing pipe with $10^3/_4$ in. outside diameter and 0.365 in. wall — a pipe within the range of sizes now in considerable demand.

Pierced billets made by the single piercing process would necessitate producing in one operation a hollow billet approximately 10 to $10^1/_4$ in. inside diameter. By the double piercing method, the billet would have an inside diameter of only 5 to $5^1/_4$ in. It is obvious that this is much more readily accomplished. Suffice it to say that this decrease in displacement can also be taken as a measure of the increase in production.

From these piercing operations just described and by which the hollow billet is roughly formed, the billet goes to the two-high mill known as the plug mill, and shown on page 43.

Rolls of this mill contain several grooves. A mandrel is inserted in one of the grooves and supported by a long bar. The hot tube is forced over the mandrel or plug and into the groove of the rolls, where it is elongated by rolling to the desired length, the wall thickness being de-



creased and the approximate outside diameter produced.

After the first forward pass the billet is returned to the front of the mill by raising the top roll automatically and using the stripper rolls shown just behind the main stand. A water-cooled bar is used to hold the mandrel and it is supported by barrel guides spaced at intervals along its length. Inasmuch as only one groove of the roll stand is used, the others may be for either a larger or a smaller size. Different sized tubes within a reasonable range can therefore be rolled without the necessity of changing the two rolls.

As the product leaves this mill it is not especially smooth of finish nor true as to diameter, but the wall thickness is definitely determined. It then passes to the reeler, which is somewhat similar to the piercing mill, being an oblique rolling operation, and which, by means of another mandrel and the rolls, burnishes or gives a finish to both outside and inside of the tube. The rolls used in this operation are flat, instead of barreled, as in the piercing mill. The tube is now slightly over the diameter desired, and it passes to a sizing mill with a single groove, or to a sinking mill (with several grooves) where it is brought to size.

Sizing and Sinking Mills

Sizing may be by two methods: *(a)* rolling between one or more pair of rolls to obtain the roundness and diameter desired, and *(b)* by the operation known as sinking, wherein the tube is passed through successive pairs of rolls of diminishing groove diameters in order to produce a tube of a diameter smaller than it is practical to roll. For example, a 3-in. tube can be reduced to 2 in. or to $1\frac{1}{2}$ in. outside diameter by sinking; sizing is accomplished in this operation also. It has usually been found necessary in using this type of mill after the reeling operation to interpose a reheating furnace to bring the material back to a temperature (usually above the critical point) at which it will be plastic enough to flow readily.

The sizing mill, as distinguished from the sinking mill, is merely a single-groove two-high mill of such dimensions to give the exact size desired, allowing of course for the contraction of the tube when cooling.

The sinking mill may consist of a continuous mill with as many as sixteen or more two-high rolls with diminishing groove diameters, the pass lines of which are in a straight line but whose axes are set at an angle of 90° with one another. These rolls, of course, revolve at different speeds to match the elongation taking place in the tube as the diameter decreases. This speed allowance is such as to overcome, in most cases, any thickening of the wall, due to decreasing the diameter of the tube.

A tube which has gone through the operations heretofore described and after delivery to the hot saw and cooling table (a view of which is shown on this page) is given the finishing operations and shipped, is known as a "hot finished" tube.

Tubes which have gone through the preceding operations and after delivery to the cooling table are sent to the draw benches for cold drawing, form a class of product known as "cold drawn tubes." A further description of this class of material will be given in a later issue.

By Charles A. Scharschu
Allegheny Steel Co.

AN INTRODUCTION TO CORROSION RESISTING ALLOYS

THIS DISCUSSION of corrosion-resisting ferrous alloys will be confined to the high-chromium steels or high-chromium irons. The metal chromium itself possesses a remarkable resistance to corrosion and oxidation at high temperatures. When it is alloyed with iron, even in moderate amounts, it imparts much of its noble characteristic to the alloy and in addition endows it with many other very desirable properties.

Chromium alloys do not exhaust the entire possibilities of corrosion-resistant metals. The addition of some other metals to iron and steel will increase the resistance to corrosion, but either the corrosion resistance of the resulting alloys is not as good as the chromium-iron alloys or their physical properties are such that they are not suitable for general application. Some, for instance, can be used only for castings.

Prior to 1922, there was practically no production of these corrosion-resisting chromium alloys in the United States, and it is only in the past three or four years that 18% chromium with 8% nickel has been produced here. The remarkable corrosion resistance of this family of alloys, however, has been recognized; their worth has been demonstrated in many fields of application, and their use has been steadily increasing. In the first half of 1930, it was estimated that their rate of production had reached 20,000 to 30,000 tons per year. When it is considered that the development of any new material is necessarily slow, it must be admitted that these alloys have properties which make them pre-eminently suitable for many applications or else this remarkable growth would not have been attained.

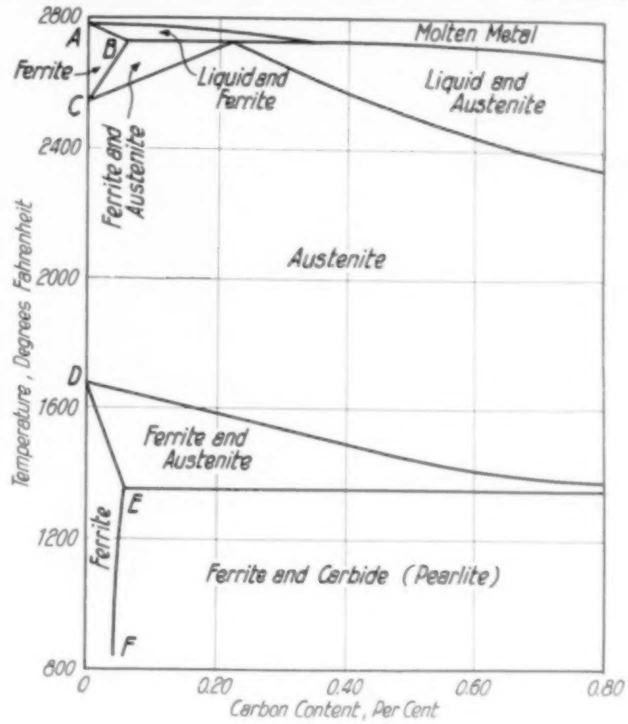
In studying the good and bad properties, characteristics, and eccentricities of the various chromium - bearing corrosion - resisting metals, one is strongly impressed with the difficulties which confront the engineer when he tackles this problem of corrosion.

The 18% chromium 8% nickel alloy represents the metallurgists' greatest achievement to date in the production of a corrosion-resisting material, and yet it will become obvious that it must not be used indiscriminately. Where proper care is taken in the study of its application, and when its eccentricities are taken into consideration during fabrication and in service, it is the most valuable of these special alloys, and its resistance to corrosion more nearly approaches that of the noble metals than any other alloy which we know. Like some people, how-

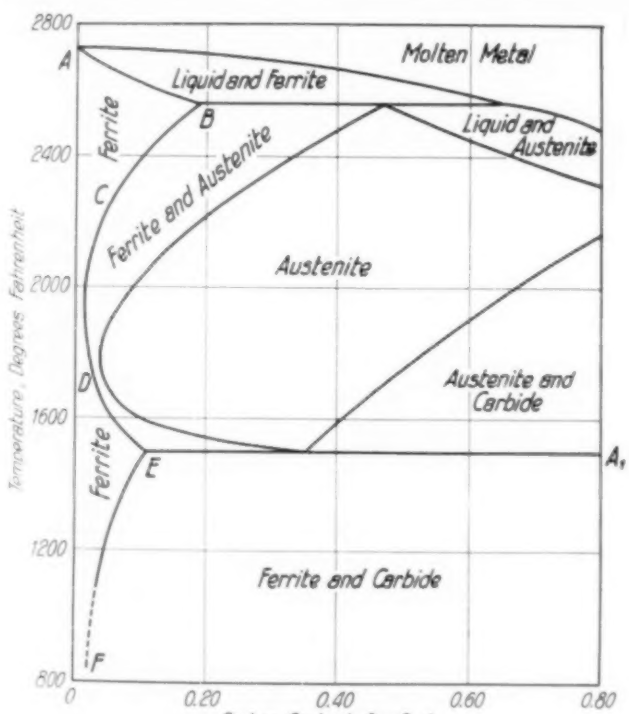
even, it has been terribly abused due to the fact that it has not been thoroughly understood.

In the application of these alloys to the problem of corrosion of industrial equipment, it is most important that we familiarize ourselves with the characteristics and eccentricities of these corrosion-resisting ferrous alloys so that we may be able to select the most suitable one for a definite service, even though tests made under some other conditions indicate that it is not as good as other alloys of a similar type. The futility of accepting any particular formula or metallic alloy as a panacea for all our ills has, in the field of medicine at least, helped to fill our cemeteries, and it is not surprising to find our industrial morgues filled with the corpses of equipment which has failed because the engineer used the wrong alloy in a location where it was not properly applicable.

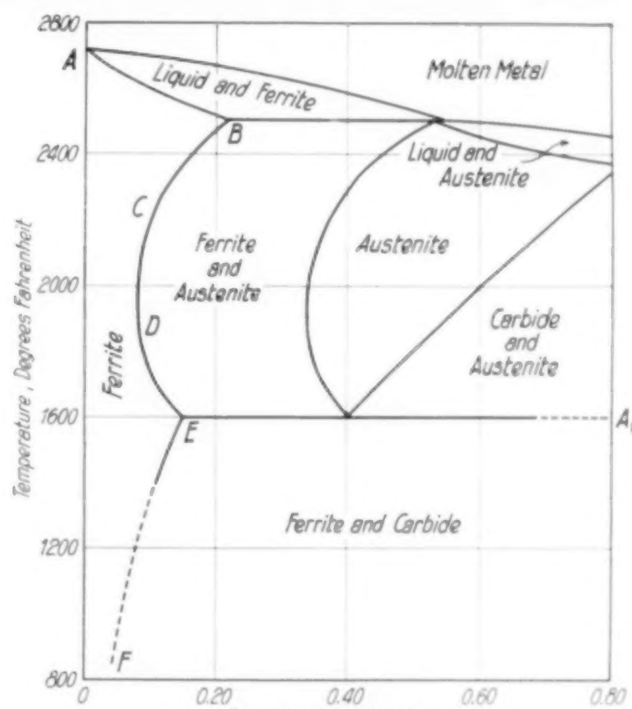
Much of that which follows has been published several times before. Some of it is new. My thanks are due to V. B. Browne, vice-president Allegheny Steel Co. in charge of research, for his help and encouragement in preparing this general statement, and for permission to present data secured in our laboratory.



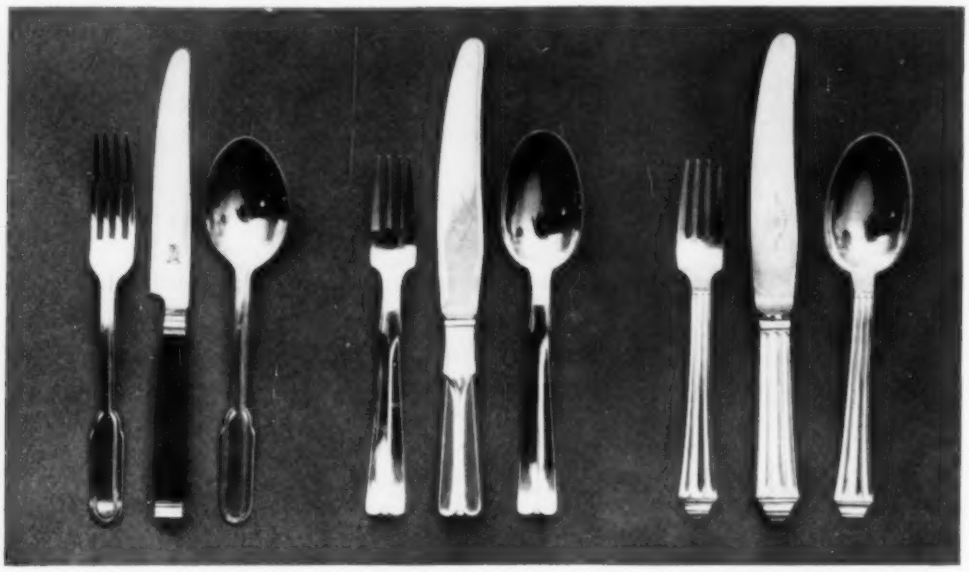
Constitutional Diagram, Iron-Carbon System No Chromium



Iron-Carbon System With 14% Chromium According to E. C. Bain



Iron-Carbon System With 18% Chromium By Bain, Grossmann and Krivobok



Examples of Flatware Designed By Craftsmen In Various Countries, Recently Exhibited By American Federation of Arts

The chromium-iron alloys which are used for corrosion resistance may be divided into three groups:

1. Chromium-iron with moderately high carbon (cutlery steel)
2. Chromium-iron with carbon under 0.12%
3. Chromium-nickel-iron with low carbon

The addition of chromium to iron causes the transformations which take place to be very sluggish, so that these alloys must be held at temperature for a longer time than is necessary with the plain carbon steels in order to be sure that the change has been completed. This sluggishness of transformation gives to the chromium alloys their valuable air hardening properties.

A great deal of study has been given the heat treatment and metallography of the chromium-iron alloys, but it was not until recently that sufficient work had been done to construct a constitutional diagram. It had been known for some time that as the percentage of chromium was increased, these alloys lost their capacity for hardening, but the metallographic constituents that existed above the Ac_1 point had not been completely identified, nor had the boundaries for the existing phases been determined, so that the reason for the loss in hardening capacity was not definitely known.

Based upon the work of a number of investigators, sufficient information has now been amassed to construct a portion of the constitutional diagram. The ones proposed by Edgar C. Bain for the 11% and the 18% chromium alloys are shown herewith.

These diagrams show how the familiar iron-carbon diagram has been changed with increasing chromium content. It shows but three stable phases: Austenite, carbide and ferrite. (Ferrite is supposed to occur in two different states: A fine decomposition product of austenite known as martensite, and a coarser grained solid solution of iron, carbon, and chromium.) We assume that these diagrams are merely tentative and like all constitutional diagrams will be subject to debate and future modification. It seems to me that the true constitutional diagram of the chromium alloys is much more complex, since this beautifully simple one does not explain all the facts.

Brearley Patents

The so-called stainless property of the chromium steels was first discovered by Brearley. His patents cover from 9 to 16% chromium and up to 0.70% carbon. Brearley stated in these patents that steels containing less than 8% chromium are relatively tarnishable whatever the carbon content, and if the carbon exceeds

0.7%, the steel is tarnishable whatever the amount of chromium. Thus, as early as 1914, Brearley realized that the role played by carbon had an important bearing upon the behavior of these steels.

These high-carbon chromium steels are the famous cutlery steels. For this purpose, two different compositions are used — carbon, 0.35% and chromium, 13.5%; and the second one is carbon, 0.65%, and chromium, 16.5%.

The constitutional diagrams show that in the annealed state, the chromium steels all contain the same two constituents at room temperature — ferrite and carbide. The latter is a complex compound of iron, chromium and carbon. Since researches have indicated that it is only the chromium in solid solution (ferrite) that imparts the remarkable corrosion resistance to chromium steels, these forged and slowly cooled cutlery steels must be heated and quenched from about 1,800° F. (well above the A_1 line) to dissolve the carbide and return the chromium again into solid solution. They may be tempered at temperatures up to 900° F. without again precipitating the carbide to any appreciable extent.

Hence, steels of this composition can only be used in the hardened condition (when they become martensitic) and, where the stainless quality is desirable, they must also be ground and polished to get a good surface. This limits their application chiefly to cutlery.

The physical properties obtainable with this type of steel are as follows:

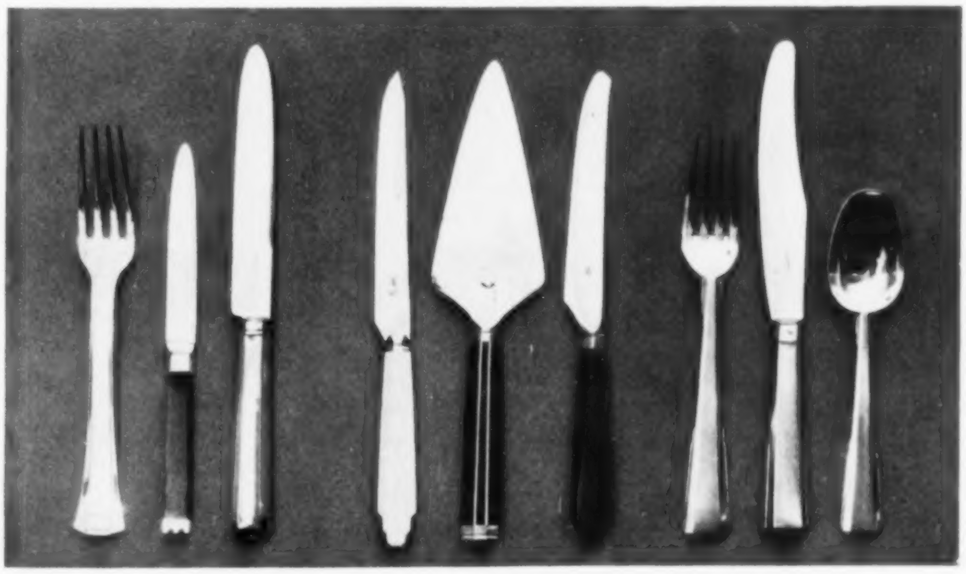
	Oil quenched from 1,800° F. and drawn at 950° F.	Tempered at 1,500° F.	Annealed
Tensile strength	260,000	130,000	100,000
Yield point	200,000	100,000	65,000
Elongation in 2 in.	8%	14%	27%
Reduction of area	20%	45%	58%
Brinell hardness	480	285	165

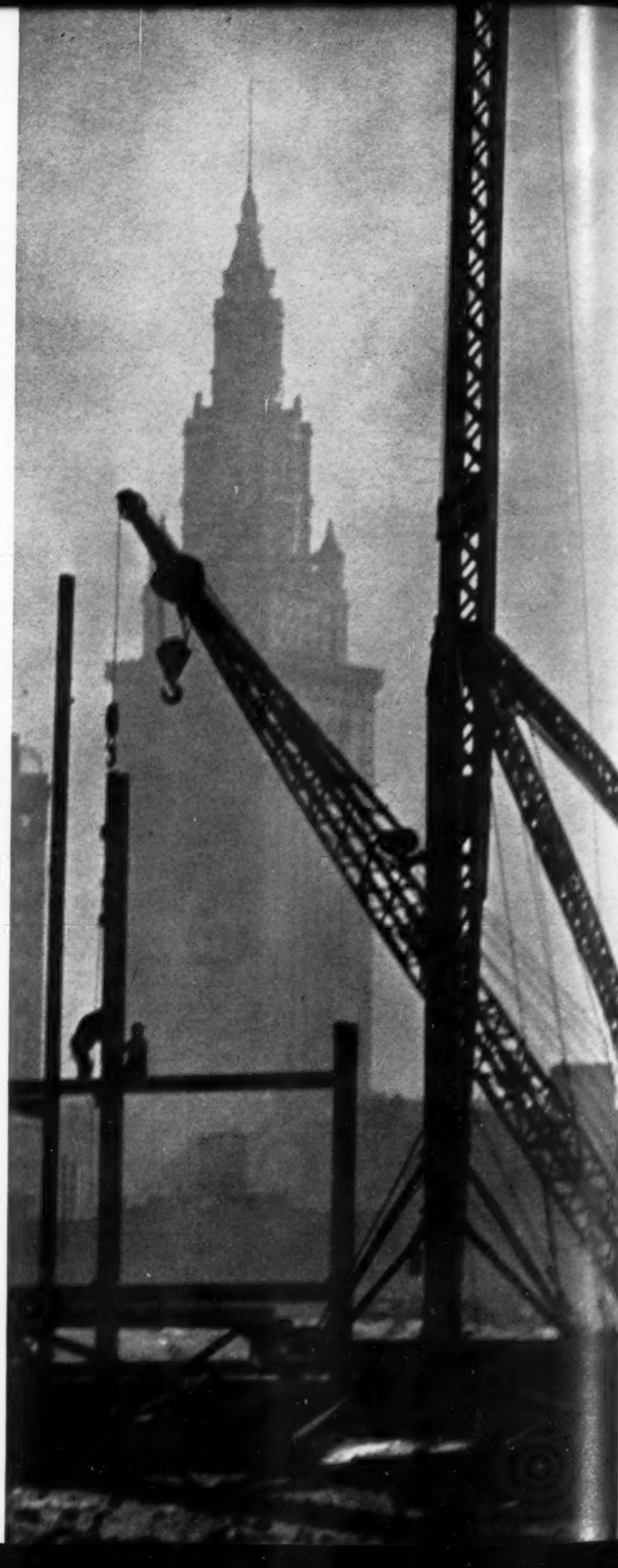
The temperature ranges for the proper handling are:

Forging	1,700-2,000° F.	
Softening	1,400-1,450° F.	220 Brinell
Annealing	1,575-1,625° F.	165 "
Hardening	1,775-1,850° F.	550 "

So much for the first classification noted on page 48. The cutlery steels described above are of great importance to the arts and are being used in constantly increasing amounts. Charles E. Herd, in an article in January Metal Progress, clearly describes the applications to heavy machinery, both as alloy forgings and as welded overlays.

A second part of this discussion will continue the subject into the lower carbon chromium-iron alloys, which are more amenable to ordinary fabrication processes, such as rolling, drawing, pressing, and welding, and are therefore of more interest to industries which are searching for corrosion-resisting metal for equipment and machine parts.





Massive Buildings Grow From Spider-like Skeletons. Arc welding has supplanted riveting many times of late in the erection of structural steel frameworks for buildings

STRUCTURAL WELDING... ITS PRESENT STATUS AND FUTURE CHANCES

By J. E. Ferguson
Manager, Manufacturing Division
The Austin Co., Cleveland

WHILE ARC WELDING has been used for some time in welding machine parts, tanks, and so on, it is only comparatively recently that it has been used successfully for structural steel work. It was about ten years ago that the Austin Co. became convinced that it was a good method of forming connections for structural steel members, and very early in our experiments it was evident that we could depend on welding if properly done. After much research work and many tests, it was clearly shown that the strength of welded joints was comparable to the strength of riveted joints.

These tests have been described frequently in the literature, and their clear indication is that riveted trusses and other structures will fail under lower loads than a welded structure (even of lighter weight), usually because of the larger secondary stresses imposed by off-center intersections at riveted joints.

Furthermore, welding now has stood the test of time. One large plate-and-angle column for a 15-ton crane runway and one plate girder for a 50-ton crane runway were completely welded in a building erected in conventional manner for the Pittsburgh Transformer Co. about six years ago. The fact that these members have continuously taken care of the loads without any apparent distress is sufficient and ample evidence of the strength of welding.

Progress has been impeded in one way by the misguided efforts of some proponents of welding. Some enthusiasts went so far as to say that building frames should be fabricated and erected at the site without any shop fabrication and even without proper drawings. Presumably all that was necessary was the desire for a building, the site, steel shipped direct from mill to site, a couple of welding machines with welding operators, and presto! the building would assume its form.

Of course, the thinking person, the architect, the engineer, and the responsible construction company know that this is far from the right method to pursue.

I do not mean to confuse what has just

The Tailor of Metals Cuts His Goods. An oxy-acetylene torch cuts as accurately as a master clothier's shears, when guided by an expert. Chalk lines serve as guides

been stated with some few buildings of simple beam and H-column construction erected by responsible builders in the field where the fabrication was simple, after the proper design had been made and the proper detail drawings furnished for the welding.

Even these simple cases, however, must be analyzed carefully from a cost standpoint to see whether the finished work is actually as cheap as when an alternate method of shop fabrication and field erection is used.

When you stop to consider the importance of a bridge or a building, and realize the amount of knowledge and skill necessary to develop it so it will be the safe structure required for public use, it can be realized what careful thought and painstaking development are necessary to attain the proper result.

Riveted structural steel is quite an old building material, as things are in this progressive age. It has done much to promote progress during the last two generations. It must also be remembered that the riveting method had to be carefully developed to satisfy engineers, building codes, and commercial conditions. In riveted work the design is carefully worked out, detail shop drawings show every rivet and hole, and these designs and details satisfy and pass existing codes. During and after fabrication in the shop, proper inspection is given to insure rivets of proper strength, spaced according to drawings. The field work also requires the same careful handling and inspection by competent men.

So it is with the new method of welding. The same careful design, operation, and inspection are required not only to make the finished structure what it should be, but to inspire the necessary confidence for the quicker development of this method of construction.

Present Achievements

Up to the present time welding has been successfully used in the fabrication and erection of some 80 important buildings, about 20 bridges (including railroad bridges which carry locomotives and cars), electric traveling cranes, and numerous steel barges and ships.

Among the important structures of the past two years may be mentioned a factory building

for Simmonds Steel Industries, Fitchburg, Mass., shop welded; the 14-story beam and column DuPont Building, Wilmington, Del., 1,600 tons field welded; the 11-story, 2,000-ton building for Westinghouse Electric & Mfg. Co., East Pittsburgh, shop and field welded; a 19-story office building for the Light & Power Co., in Dallas, Tex., shop and field welded; 3,400 tons partially shop and field welded in a 14-story office building for Southern California Edison Co., Los Angeles; 1,314 tons field welded skeleton for the 14-story office of Edison Electric Illuminating Co., Boston; and 1,000 tons in a mill-type building for the lamp department of General Electric Co., Cleveland, shop and field welded.

This is indeed a notable list. Obviously, the new method must have some outstanding advantages. Among these may be listed the following:

1. Silent construction. This feature has particular advantages in congested areas or in the neighborhood of hospitals, hotels, and private residences.

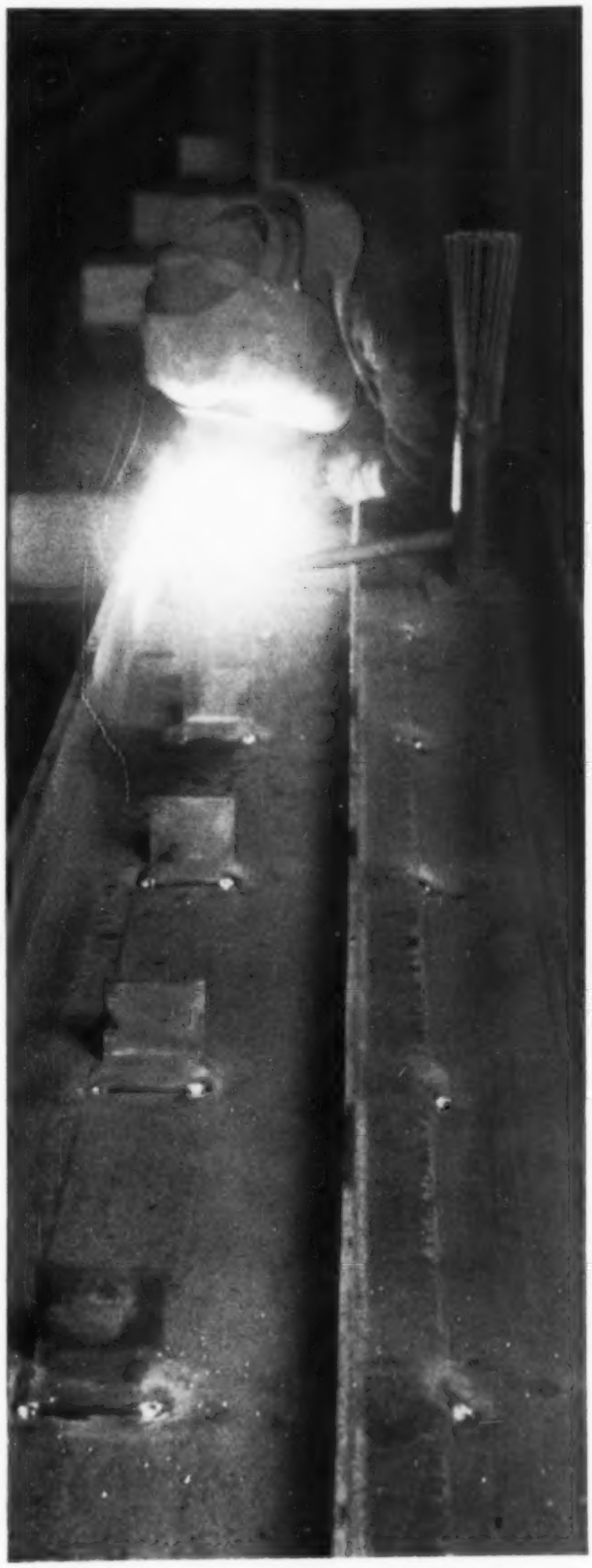
2. Smooth finish. In trusses the lines of the chords and web members are unmarred by large and unsightly gusset plates as well as innumerable rivet heads. Fewer niches remain to accumulate dirt and foster corrosion.

3. Economical construction. Welded steel offers an excellent avenue to reduce costs, both in the fabrication and erection. There is a substantial saving in weight on account of the possibility of more economical distribution of structural material.

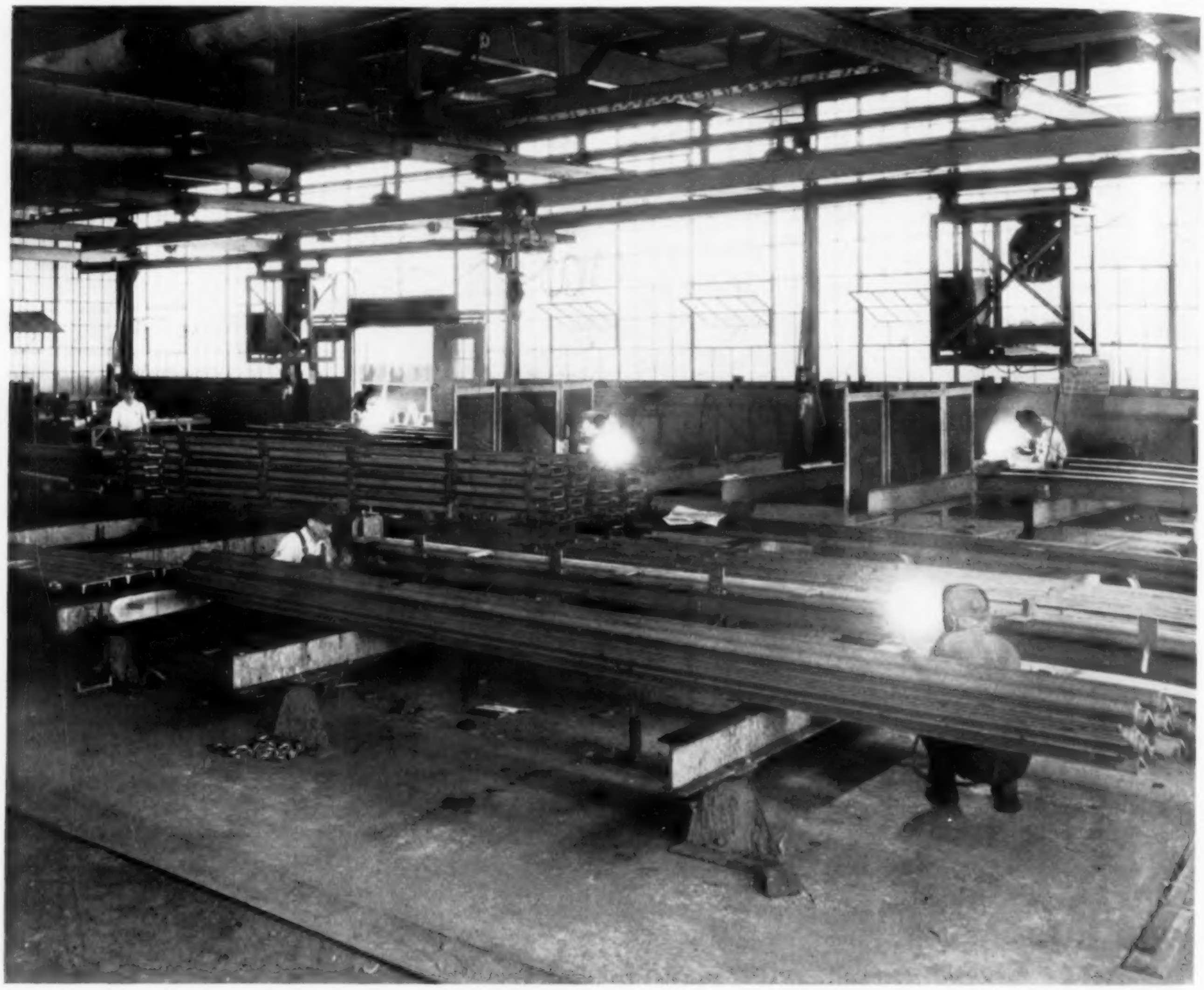
4. Stronger and stiffer construction. Welded trusses, although lighter than riveted trusses designed for the same loading, are stiffer and easier to handle in the shop and field. The difference in stiffness between a welded crane girder bridge and one fabricated by riveting is very noticeable when standing on the crane in motion.

5. Simplified design and details. An example of this is in the truss, where the gusset plates are eliminated and the web members welded directly to the chords.

6. Flexibility. Additions can be made to existing structures and members may be strengthened easily by the welding method. Many railroad bridges have been strengthened to take care of the increased live loadings. This



Finish Welding a Floor Beam. Its several parts have been tacked together by a previous operator. This man will do all further welding except final assembly in the structure which is done on the job



Austin Company's Fabricating Plant. Material being welded is laid on grids for operators' convenience. Welding machines, suspended overhead from monorails, can be moved easily from place to place

would be a big task and much more costly if done by riveting. Field alterations caused by errors in shop work or changes in design are more easily made.

7. Ease in erection. Welding requires more simple and less expensive stagings than for riveting. The accident hazard during erection is greatly reduced. There are no falling rivets or drift pins; on some buildings this has been quite serious. The fire hazard is also reduced by the elimination of hot rivets and rivet forges.

It is not to be supposed that we will be content with the present competitive situation in the structural steel industry. The above advantages are real, and can be translated into commercial economies. In other words, welded fabrications can now be offered at competitive prices with riveted fabrications, and the Austin Co. shops near Cleveland are equipped with parallel bays, one for each kind of work, so shop welding can be done economically.

There are some things, however, which are still hampering the wider acceptance of the new method, and the first one on the list is the restrictions imposed by many municipal building codes.

At the present time, only 100 cities have changed their building codes to permit the welding of steel structures. In some other cities, welding is possible when the building commissioner uses his discretionary powers under the building law. This will usually allow new mate-

rials or methods under such regulations as the commissioner may fix.

The office building for the Edison Electric Illuminating Co. in Boston was field welded in the latter manner. The requirement fixed was that the consulting engineer should certify that the building, as pertains to the welding, should not exceed the stresses and strains permitted by law, and at the completion of the welding, he should certify by a final affidavit that the building does so conform.

The excuse for the delay in setting up a welding code in a given city may be that it is somewhat difficult to find the proper citizens not only competent to prepare a good and suitable code for welding steel structures, but also to know that such requirements are intelligently and properly carried out.

An excellent and thoroughly safe alternative is to adopt a first-class standard code for fusion welding. A logical code of this kind would be that of the American Welding Society. By adding this document to their building codes, a great many cities would be able to permit welded construction much sooner than in any other way. It is very certain that this code would be as good as could be obtained.

Most progressive architects, engineers, and construction companies are quick to perceive the advantages of this new method, and will turn to it when they can satisfy themselves that the work can be carried out without any more trouble than is experienced in one of the familiar riveted structures.

Probably the most important factor determining the promotion of the welding process has to do with the proper fabrication and erection of the future structures. This involves several important items:

1. The use of correct sections.
2. Logical designs for the particular use.
3. Suitable details for welding.
4. Correct plant layout, both in fabrication shop and in the field.
5. Right equipment, particularly welding machines, jigs, and handling equipment.
6. Proper supervisory organization and welding operators.
7. Proper inspection.

Some of these items deserve a few words in explanation.

At the present time, the rolling mills are not able to furnish all of the steel sections required for the most efficient and economical design of welded steel work. In time, they will roll some of them when the demand is sufficient to warrant the purchase of the required rolls. In the meantime, special sections called for in the design may be obtained by cutting or trimming stock shapes. Large T-sections for chords of trusses are now obtained by splitting broad flange I-beams along the center line of web.

It must be recognized that design of welded steel members is entirely different from the design of riveted members if progress is to be made. An example is a roof truss. For welding, the most economical design usually calls for a large T-section for the top and bottom chords with either angles or smaller T-sections for the web members. All gusset plates are usually eliminated. *(Continued on page 108)*

Detail of Welded Joint in a Roof Truss. A perfect regular bead free from blow-holes is one indication of a sound weld

By E. T. Youd
Chief Metallurgist
The Bullard Co.

LEAD FILM PROTECTS METAL UNDER SCALE

A NEW PROCESS for cleaning forgings was discovered by the Bullard Co., Bridgeport, Conn., in 1926 by force of necessity. The story of its development is worth outlining because in so doing its advantages can be made clearer by comparison with other methods, tried and discarded, during the developmental period.

It came about in this way: Bullard makes machine tools, as is doubtless well known, but the establishment of a division to manufacture bumpers for automobiles sharply focused attention on the problems of removing heat scale, because bumper bars cannot be polished rapidly and economically unless it is first removed completely from the surface to be polished.

Steel bars for bumpers were made from S.A.E. 1095 steel, having the following composition: Carbon, 0.95 to 1.05%; manganese, 0.25 to 0.50%; silicon, 0.30% maximum; sulphur, 0.050% maximum; and phosphorus, 0.040% maximum. After forming they were heat treated by quenching in oil from 1,500° F. and drawing at 900° F. to Brinell hardness of 418 maximum.

This heat treatment left the bars covered with a hard black magnetic scale (principally Fe_3O_4). Slight rusting also occurred, so that the scale or oxides to be removed contained both the black and the red (Fe_2O_3). It was not uniform in thickness, but it had a tendency to build up behind and within the "eyes" of the formed bumper bars.

To remove this scale, pickling in sulphuric acid was first tried. Various inhibitors were also used. When this did not give satisfactory results acid mixtures were substituted. Then electrified pickles were tried — with the work as the cathode and then as the anode.

In general, the results were the same with all forms of pickling, namely, the work was never thoroughly cleaned without marked pitting, etching, and hydrogen embrittlement. Pitting and etching made it necessary to grind the surface of the bar to the bottom of the deepest pit mark before a satisfactory job of polishing could be done. This greatly increased the cost of polishing. Embrittlement caused the failure of a large number of the bars under the bend test of the Underwriters' Laboratory, which requires that a bar stand a deflection of ½ in. in a span of 6 in. without permanent set or other damage to it.

Sand rolling was then tried without success. Certain spots were not cleaned at all; further-

more minute flakes of scale remained imbedded in the steel surface. The difficulty of untangling a mass of bumper bars after the rolling operation was also a distinct objection to this attempt at cleaning.

Sand blasting was next tried with results similar to those obtained by sand rolling. Additional objections to sand blasting were the cost of power, the nozzle wear, and the destruction not only of the sand blast apparatus but also of all other equipment located in the vicinity of the sand blast. Further was the health hazard to the employee. Steel shot, when substituted for sand, did not improve any of the conditions or results.

Scratch brushing was next tried. It did not do a thorough job, and it was as expensive as an extra polishing operation.

Such obvious defects of all the methods stated above led to experimental work on the fundamentals of the pickling operation and to the discovery of a process which has been called the "Bullard-Dunn Process," and for which patents have been granted. It solved all the problems of scale removal from bumper bars. Naturally it was promptly put to use for cleaning all heat treated parts used in the machine tools manufactured by this company.

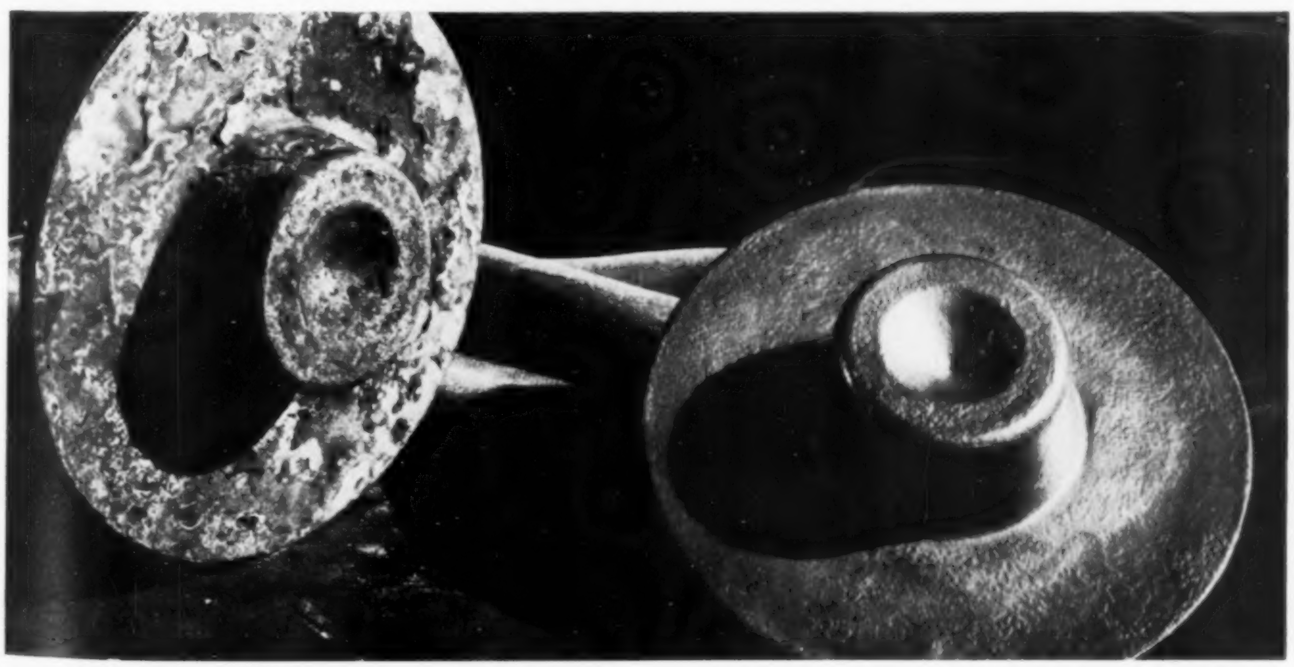
The process itself is simple and inexpensive. Parts to be cleaned are first freed from grease or oil, if necessary, using any suitable method of grease removal. They may then be hung on hooks from a copper bar extending across the tank-top, this bar being connected with the negative pole of a direct-current generator. Thus the work is a cathode; the anodes are usually lead plates. (Appropriate changes would be made in the set-up for cleaning small parts in a barrel.) The solution is maintained at 150 to 170° F., and is a sulphate-chloride bath.

Immediately the iron forging or other article to be de-scaled is immersed, hydrogen gas is generated by electrolysis of the water content of the solution, and forms between the scale and the metal surface beneath.

No Hydrogen Absorbed

A small but effective amount of lead is in the solution, and a microscopically thin film is deposited on the base metal itself immediately it becomes exposed. This film not only prevents any attack on the iron, but also effectually prevents the absorption of any hydrogen into the intercrystalline cement between metallic grains. Thus the possibility of hydrogen embrittlement is avoided.

Furthermore, since lead will not deposit on lead itself in the electrolyte used, prolonged immersion in the bath does not increase the thick-



ness of the adherent film on the areas which were first cleaned, but merely results in the deposition of a lead sponge or powder, which is removed by rinsing. The lead film will not interfere with machining or drawing operations nor will it clog grinding or polishing wheels.

Where metals are cleaned prior to welding or electroplating with other metals, or where it is advisable to avoid even a trace of contamination — as, for example, in hot galvanizing or hot tinning — the lead deposit can be removed quickly and completely by treating the metal anodically in an alkaline bath maintained at 200° F. In this de-filming treatment there is no action on the ferrous metal itself.

Critical Conditions Absent

Experimentation with the process shows that it operates without appreciable loss of efficiency through a fairly wide range of temperature, chemical and electrical control. Nothing about it is "critical" and therefore it lends itself readily to the requirements of continuous operation by ordinary operatives. As no dependence is put on a gas film for inhibition, moderate current densities are sufficient (60 to 75 amperes per sq. ft.). None of the chemicals required give rise to toxic fumes, nor is the hydrogen or slight amount of chlorine evolved sufficient in volume to demand costly ventilators. Current is furnished by a standard 6-volt direct current generator familiar to electroplaters.

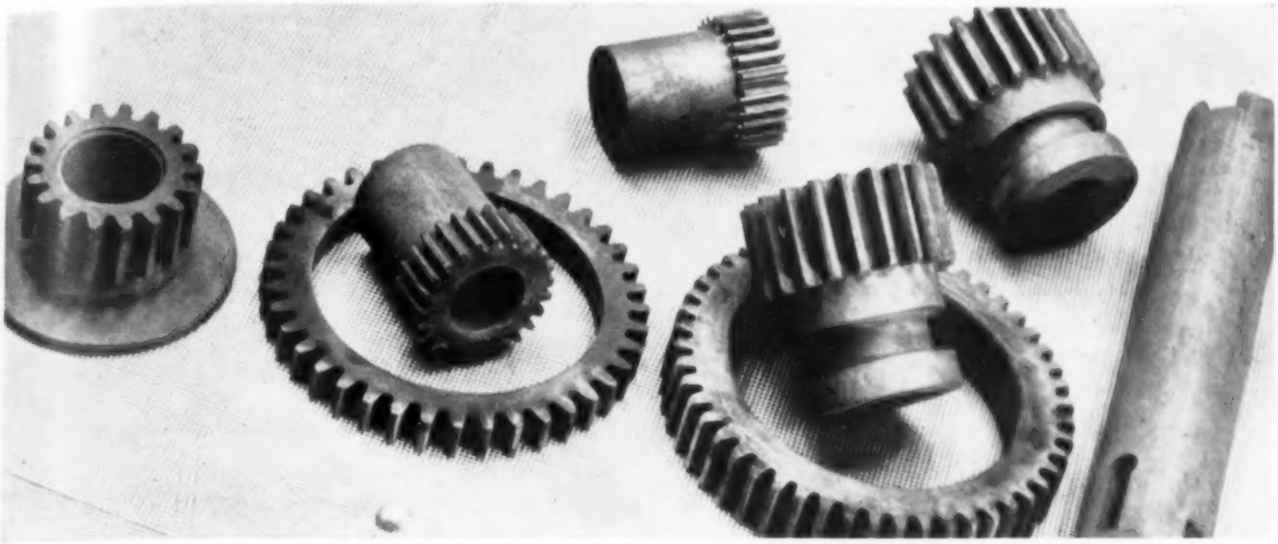
A brief account of the improved results accomplished in the Bullard plant since the invention of this process is as follows:

On bumper bars the first polishing wheels used prior to the discovery of this process were set up with No. 36 electric furnace abrasive grains. Subsequently, and with the same steel-bar stock, the first polishing was done with wheels set up with No. 90 grains. Furthermore, as there was no glazing of wheel faces from scale, the life of the polishing wheel set-ups was lengthened by more than 300%.

Due to the complete removal of scale from the back side of the bumper bars, and due to the improvement of the electrical contact between the electroplating racks and the "eyes" of the bumper bars, the quality of the electro-deposited coatings of nickel-copper-nickel and chromium was improved so that rejections were reduced to a negligible quantity and the "salt spray life" lengthened from an average of 25 hr. to a minimum of 400 hr.

Successful solution of the bumper-bar problem led the officials to adopt the new process for cleaning all surfaces of heat treated alloy steel parts entering into the construction of the Bullard line of vertical turret lathes and mult-au-matics. Some manufacturing economies were immediately apparent.

Prior to the use of the new method of cleaning, 20 men were regularly employed in cleaning heat treated parts. The Bullard-Dunn installation is operated by two men, who, as they



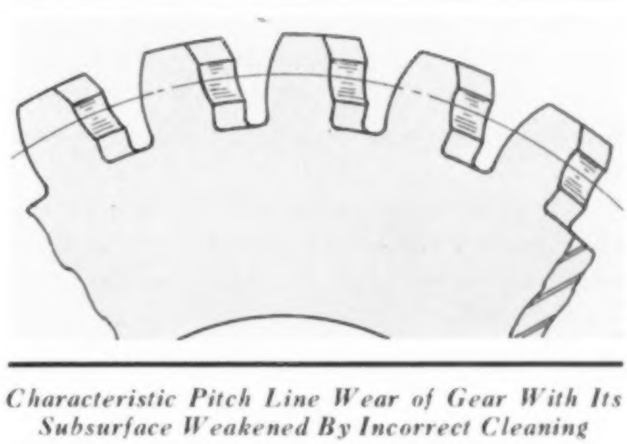
Gears and Lathe Parts, Covered With Heat Scale, Can Be Cleaned In 5 To 10 Min., Ready For Finish Grinding and Assembly

clean, also inspect and mark or set aside pieces which seem faulty. The number of grinding wheels used for after-grinding has been reduced to half the former inventory, and the life of the grinding wheels is considerably longer because frequent wheel dressing has been rendered unnecessary.

Some noteworthy improvements in the operation of our machine tools in customers' plants have also been noticed. It is vital to remove every trace of scale from heat treated gears. Failure to do so results in the formation of a highly abrasive mixture of scale and oil, which circulates through the lubrication system of the machine tool and causes rapid wear of gear teeth, shafts, and bearings. Perfect cleaning therefore means less trouble with wear after the tool starts operation.

We are further inclined to believe that pickling of any sort causes subsurface damage to the metal, appearing to leave it in a porous state. This is clearly proven by the characteristic pitch line wear (shown in the opposite sketch) of gears that have been pickled. Sand or shot blasting does not clean gears thoroughly since depressed surfaces, as for example the roots of teeth, are not effectively reached by the stream of abrasive. Furthermore, sand blasting destroys the dimensions of precision gears, and contours thus distorted cannot always be restored by after-grinding. None of these difficulties arise with the new cleaning method.

In summary, we have found the following advantages to reside in the Bullard-Dunn process: It removes scale and oxides from metal surfaces without damaging the underlying metal surface or subsurface. There is no pitting, etching, or other evidence of intergranular action, to be expected with inhibited pickling or electrified pickling. Dimensions are preserved absolutely. Through the over-voltage action on the lead film deposited on the clean metal areas as these appear, the bottom areas of recesses may be cleaned as thoroughly as are the top or more exposed surfaces. Hardening cracks and other defects are thus rendered visible, so that faulty parts may be rejected prior to the expenditure of further useless and expensive work.



Characteristic Pitch Line Wear of Gear With Its Subsurface Weakened By Incorrect Cleaning

EFFECT OF LEAD . . .

IN BRASS AND BRONZE

machinability

..workability

..weldability

By H. P. Croft
Chase Brass & Copper Co.
Cleveland

PRESENCE OF LEAD in copper alloys has been looked upon with more or less disfavor in the past. Specification writers for purchasers of copper alloys have prohibited it to such an extent that unwittingly they many times defeat their own ends by denying small amounts of this often-useful metal.

The purpose of this paper is to show that lead in copper alloys is not as harmful as believed, but also to show that when used with discretion it may be quite beneficial in a majority of cases. It will be shown that by means of lead it is possible to increase, even double, the machinability of well-known brasses without any sacrifice in the tensile properties. On the other hand, lead should be kept at a minimum figure in welding rod, and should be limited in thin sheet intended for severe stamping operations.

As is well known, metallic lead is gray in color, very soft, and of low strength as compared to other metals. Its specific gravity is high, being 11.4, and its melting point very low, 326° C. These two figures should be borne in mind, as they affect its influence on the properties of alloys in which it is present.

A review of the information available on the copper-lead equilibrium diagram has been prepared by Holder, and he says that copper and lead are completely insoluble in each other in the solid state. (A eutectic alloy containing 0.06% copper has a freezing point about 1° C. below that of lead.) Furthermore, a recent paper by Bauer and Hansen concludes that lead is insoluble in alpha and beta brass, as they have detected less than 0.1% lead in both brasses under the microscope.

Photomicrographs show that 0.1% lead is present as small globules in an alpha brass. A greater percentage of lead in an alpha-beta brass finds it largely, if not entirely, at the grain boundaries.

Lead is present in brass and other copper alloys in two ways, first, as an impurity (due to the fact that commercial zinc contains more or less of this element according to the class of zinc used) and secondly, as an element added intentionally in order to obtain certain desirable properties. As an impurity, lead may occur in brass in amounts ranging from 0.01%

to 0.40%, depending upon the grade of spelter (zinc) and the kind of scrap used in melting the metal. As an intentionally added metal, it occurs up to 4%, the exact amount depending upon the purpose for which the alloy is intended, as well as the operations to which it will be submitted.

Lead In Forging Brasses

As to the effect of lead on the hot working of brasses, probably the best work which has been done on this is that of Bunting, who reached the following conclusions:

The chief effect of the presence of lead is mechanical, the lead existing as small globules and increasing the brittleness at high temperatures. The lead causes a slight but uniform decrease in the impact strength. It does not, however, affect the limit of the brittle range appreciably.

The presence of lead in brass should be avoided in connection with apparatus working at high temperatures, but for hot forging work no harmful result will occur, provided the temperature of working is kept sufficiently high. It is consequently the practice of Chase Brass & Copper Co. to maintain the lead content of free-turning forging brass between 1.5 and 2%, and they find that such an alloy forges very nicely and at the same time contains enough lead so that it will machine readily. This general property of machinability will be discussed at length later in this paper.

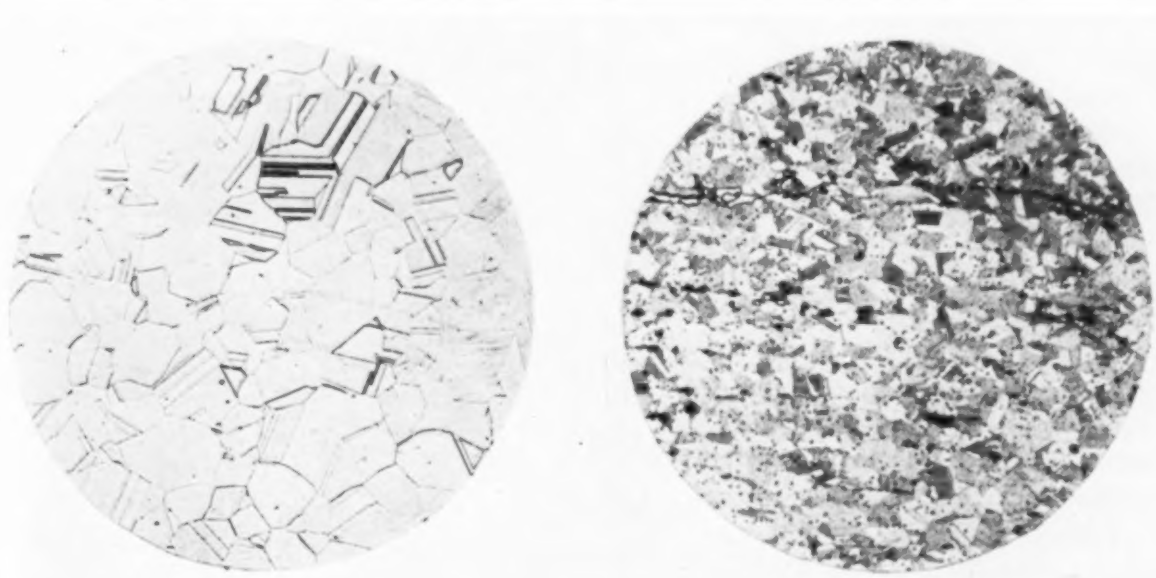
For shearing or ordinary blanking of brasses in heavy sections, lead is decidedly beneficial. The presence of lead will result in a cut which is quite smooth and free from burr, as compared with the shearing of an unleaded piece of the same gage.

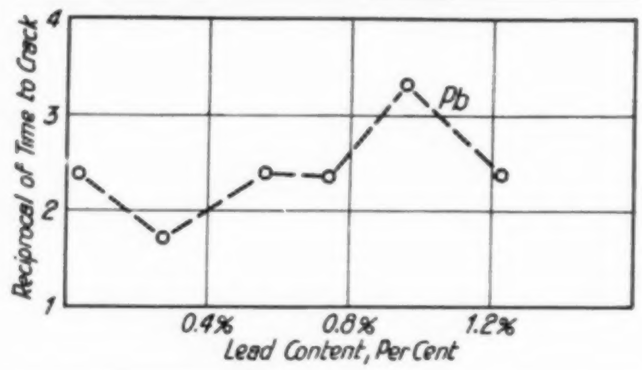
Another instance where its use is absolutely essential is in engraving brass. Its copper content varies from below 60 up to 65%, but the lead is held between 1.0 and 2.5%. This enables sharp, clear characters to be cut.

On the other hand, there are some uses of brass and copper alloys for which lead should be held at a low figure. Among these is welding. We studied the effect of small quantities of lead (0.01 to 0.48%) on the surface appearance, adherence, and fuming properties of welds made with a naval brass welding rod, containing approximately 60% copper and 0.75% tin. Taking all the characteristics into consideration, we decided that a low limit should be specified for lead content of welding rod.

In so far as the effect of lead upon the resistance of brasses to corrosion is concerned, this element in small amounts, that is, roughly

Small Globules of Lead Appear in Alpha Brass When This Metal is as Low as 0.1%. Larger amounts in an alpha-beta brass favor the grain boundaries. It apparently is entirely insoluble in commercial copper-zinc alloys





Tendency to Season Crack, as Affected by Lead Content in Brass Tubes Sunk from 1 in. x 0.060 in. to 0.813 in.

Effect of Lead on Bending Properties

Lead Content	Bend Along Grain	Bend Across Grain
0.027%	In distress at 135°	O.K. at 180°
0.063	Cracked at 135°	In distress at 180°
0.15	Cracked at 135°	Cracked at 180°
0.35	In distress at 90°	In distress at 135°
0.99	Cracked at 90°	Cracked at 135°
2.63	Cracked at 90°	Cracked at 90°

This is illustrated by the graph, at top this page, showing the effect of lead on high brasses. The tendency to season crack, as measured by the reciprocal of the time to crack in the standard mercurous nitrate test, is found to be about the

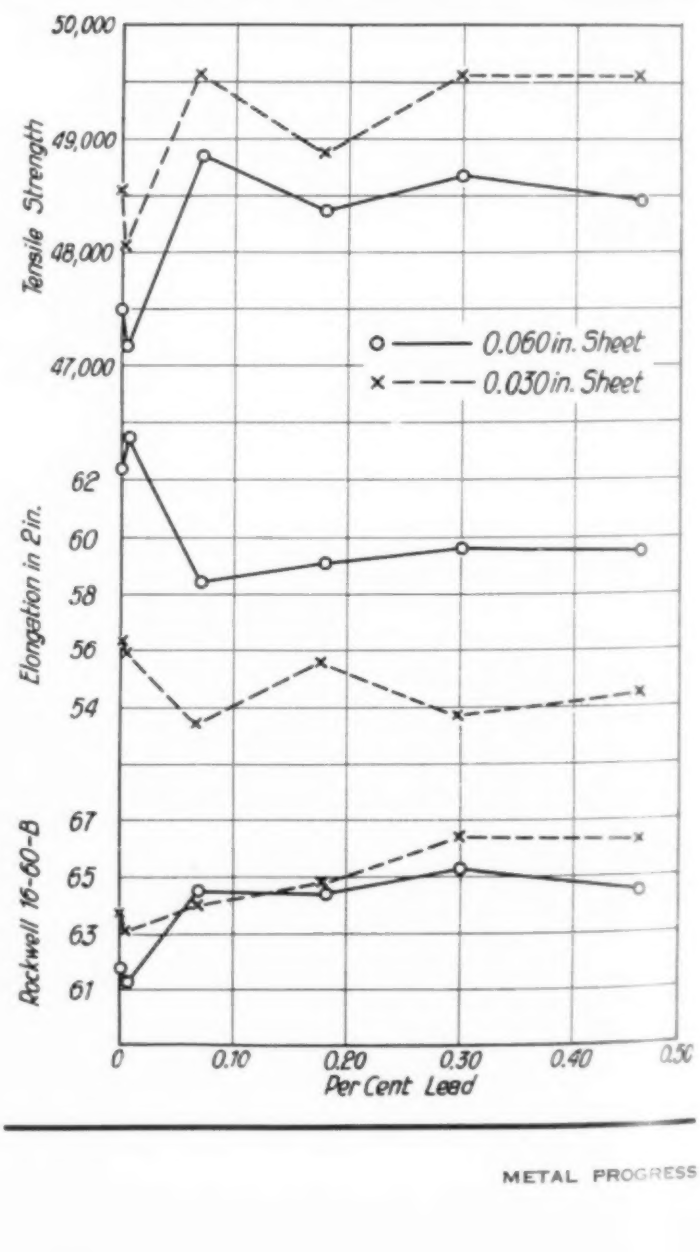
under 2%, is certainly not harmful and in greater amounts than this, decidedly beneficial.

The effect of small lots of lead in high brass which is to be cold worked depends upon other conditions than the lead content alone. For riveting, quantities of lead up to 0.2% have apparently little effect. Above this, however, the physical characteristics of the rivets fall off rapidly as shown by the hardness and flattening tests.

The effect of lead on the bending properties of brass is a direct function of the lead content. It does render brass and copper alloys somewhat brittle on bending. This effect is, of course, more pronounced when the bend is made across the grain. (See the tabulation of test results in the next column, on a brass containing 65% copper.) The sheet tested was 0.040 in. thick and the temper four numbers hard. It will be noticed, however, that within the range of lead found as an impurity in high brass (up to 0.15%) the effect is very slight. On the other hand, the sheet containing 2.63% lead cracked when bent along the grain to 135°, even when only two numbers hard.

A paper by D. K. Crampton of the Chase organization before the A.I.M.M.E. a year ago demonstrated that lead has practically no effect on season cracking.

Effect of Lead on Properties of 70:30 Brass Sheet. Plotted points represent the average value for five temperatures of anneal. Note characteristic relationship between thickness of sheet and strength and ductility



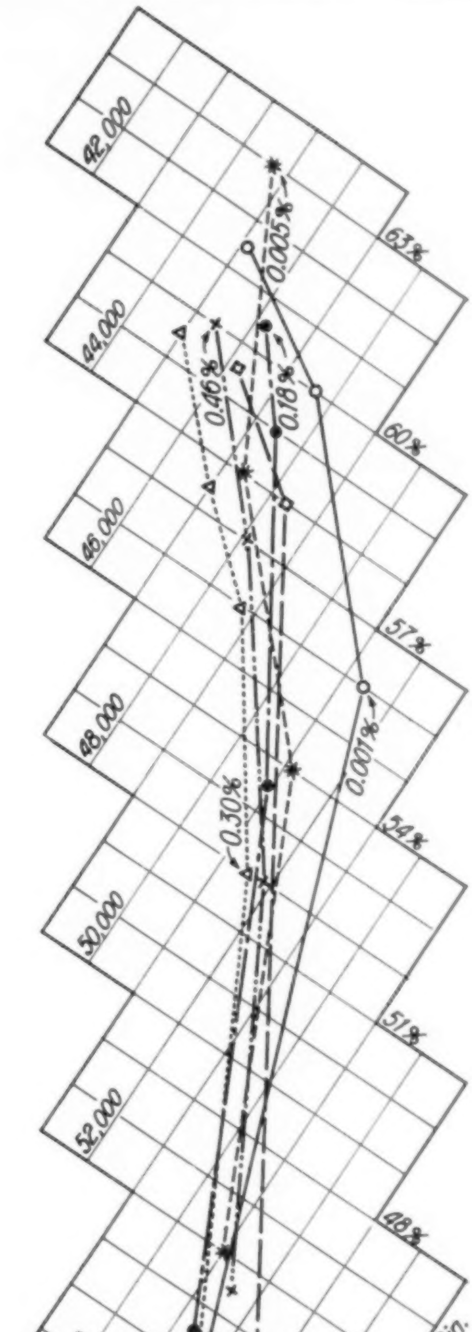
same for brasses containing from about 64 to 70% copper.

Brass tubes sunk from 1 in. x 0.060 in. to 0.813 in. diameter are internally stressed to about 46,000 lb. per sq. in. in a circumferential direction, and this stress causes them to crack in about 0.43 min. (reciprocal 2.3). The curve shows similar data for 66% copper brass containing increasing amounts of lead. Time to crack in $HgNO_3$ varies irregularly from 0.30 to 0.58 min. (reciprocals 3.3 to 1.7).

Ten-foot lengths of each of these lead-bearing tubes were annealed on a Snead electric resistance annealer, giving an extremely rapid heating effect. All of them containing 0.28% lead or more cracked the entire length, and this is a measure of the tendency to "fire cracking" in fabrication.

This tendency, however, can usually be overcome by correct layout of drawing operations, and if this is impossible, by low-temperature annealing before an annealing at the higher temperatures which might induce fire cracking.

Lead is admittedly deleterious in its effect on the drawing and forming of articles from brass sheet where the operation is very severe, especially in thin gages and when the forming of the article involves forcing the metal around sharp corners.



Tensile Strength Plotted Against Elongation for 70:30 Brass Sheet, 0.030 in. Thick, as Tested After Various Anneals. Each curve represents a sheet with a certain content in lead, as noted. Since curves intertwine, it is to be concluded that lead has no consistent effect on tensile properties

This effect, however, is exaggerated in the minds of many. With anything but the severest of draws, and with metal of heavier gages, lead is not harmful for drawing and forming operations.

In connection with this, I recall an instance where a fired 75-mm. shell (a sample from a large number) was submitted for analysis in considering the purchase of scrap. The formation of this shell, of course, involved very severe drawing and forming. Much to our surprise, it contained 1.75% lead. It had not burst in firing, and consequently was able to withstand this very severe test of use.

Just how much influence this element has upon the physical properties of cartridge brass sheet is best illustrated by a diagram (page 62) of the physical properties of this mixture as a function of the lead content. These show that the tensile strength and Rockwell hardness ($\frac{1}{16}$-in. ball, 60-kg. load, B scale) increase very slightly with the addition of lead, while the elongation falls off only a very little for minute amounts of lead, and then remains constant. Curves are given for two thicknesses of sheet, and each point plotted is the average value for five different temperatures of anneal. This data has been replotted in the graphs alongside which give the tensile

EFFECT OF LEAD ON MACHINABILITY OF COPPER AND BRASS

	Non Leaded High Brass	Leaded Free-Turning Rod	Non Leaded Muntz Metal	High Brass Tubes		Conductivity Copper			
				Non-Leaded	Leaded	Pure	Free Turning Alloys		
Analysis									
Copper	66	61.5	59.1	71.5	66	99.9	99.0	98.4	93.4
Lead	0.14	3.35	0.13	0.15	1.01	0.07	1.03	1.81	1.61
Zinc	Balance	Balance	Balance	Balance	Balance	None	None	None	None
Nickel								0.49	—
Silicon									0.08
Tensile Properties									
Ultimate	54,500	56,700	70,900	84,400	82,000	39,600	38,700	51,100	35,700
Yield Point	43,600	44,400	55,800			37,100	36,600	47,000	33,100
Elongation in 2 in.	47	32	31	20.5	17	36.5	32	30	34
Rockwell B Hardness	101	100.5	105.5	108.5	108	82	73	79.5	85
Conductivity	27	25				100	79.5	59.7	79.6
Machinability									
Saw Cuts	29	10	28	48	25	37	10	8.5	8.5

strength as a function of the elongation, and a different curve has been drawn for each brass as its lead content increases. As these lines intertwine and lie close to one another, it is a clear indication that the effect of lead on the tensile strength and elongation is slight.

Machinability

By far the most important function of lead in the copper alloys is its beneficial effect upon machinability. Were it not for the presence of this very useful element, automatic screw machines would turn out brass parts at a much slower speed than is obtained at present. What this means can hardly be appreciated by one who has not tried to operate at screw machine speeds without having free-cutting stock to feed into it.

Comparative machinability is measured in our laboratory by the number of saw strokes necessary to cut through a rod of given diameter on an ordinary power hacksaw. This may seem to be a crude method of measurement, but it shows the very marked effect of lead on machining properties. Check tests were, of course, made in every instance, care being taken that the saw was in as nearly the same condition as possible so far as sharpness is concerned. Remarkably close results were obtained. It is believed that this is a fairly good indication of the ability of the rod to be machined easily.

Physical properties are also given in order to show that these do not fall off to any appreciable extent for lead contents sufficient to benefit the machinability. Rockwell hardness is reported as determined by a $\frac{1}{16}$-in. ball under 60-kg. load and read on the B scale ("16-60-B" according to notation recommended by Mr. Crampton). Electrical conductivity is given as per cent of the international annealed copper standard.

The first three columns in the table on this page compare the properties of free turning brass rod containing over 3% lead with high brass and muntz metal. Note the remarkable increase in machinability as shown on the last line. This is due to the addition of lead, because the copper content of the free turning rod lies between muntz metal and high brass, as can be seen from the analyses quoted.

Effect of lead on high brass tubes is shown in the next pair of columns in the same table. Although the copper contents are different, the analyses are within the range for which the physical properties are practically independent of copper content. Here again the addition of 1% lead is responsible for a remarkable change in the machining qualities of a metal.

There has always been more or less of a demand for a free cutting copper rod. This demand prompted the Chase companies several years ago to produce such a rod containing 1%

EFFECT OF LEAD ON MACHINABILITY OF BRONZES

	Chamet Bronze		Phosphor Bronze		Commercial Bronze	Hardware Bronze	Leaded Bronze
	Non-Leaded	Leaded	Non-Leaded	Leaded			
Analysis							
Copper	60.3	60.6	95.6	94.8	90.2	88.5	88.3
Lead	0.075	1.24	0.075	0.98	0.075	2.07	3.74
Tin	0.75	0.75	4.12	4.01			4.0
Zinc	Balance	Balance			Balance	Balance	3.95
Iron			0.01	0.02			
Phosphorus			0.21	0.19			
Tensile Properties							
Ultimate	72,700	70,600	79,900	81,300	46,800	43,800	54,400
Yield Point	58,300	55,000	62,500	65,900	42,600	41,100	48,400
Elongation in 2 in.	26	22.5	21	18	34.5	33	42
Rockwell B Hardness	107	104.5	109	108	93	91	105.5
Conductivity	27		16.7	16.3	43		
Machinability							
Saw Cuts	23	13	29.5	15.5	35	8	8

lead. This is used considerably for blowpipe tips and other places where a high electrical or thermal conductivity, together with good machinability, has been desired. When lead goes higher than 1%, it is difficult, if not impossible, to distribute it uniformly in the alloy. Consequently, addition agents have been used in an endeavor to raise the lead content of this mixture. Properties and machinability of some specially made alloys of this kind are shown in the right-hand column in the table on the opposite page.

The alloy listed in the last column gives promise of being the best for this purpose, since it combines excellent machinability with good physical properties and does not wear tools to the extent that the nickel-bearing alloy does. This silicon-lead-copper is known as "Special Leaded Copper Rod LLS" and can be machined quite rapidly on automatic screw machines as well as drilled for torch tips. Since thermal conductivity is usually proportional to the electrical conductivity, it can be seen that this will be quite high.

Leaded Bronzes

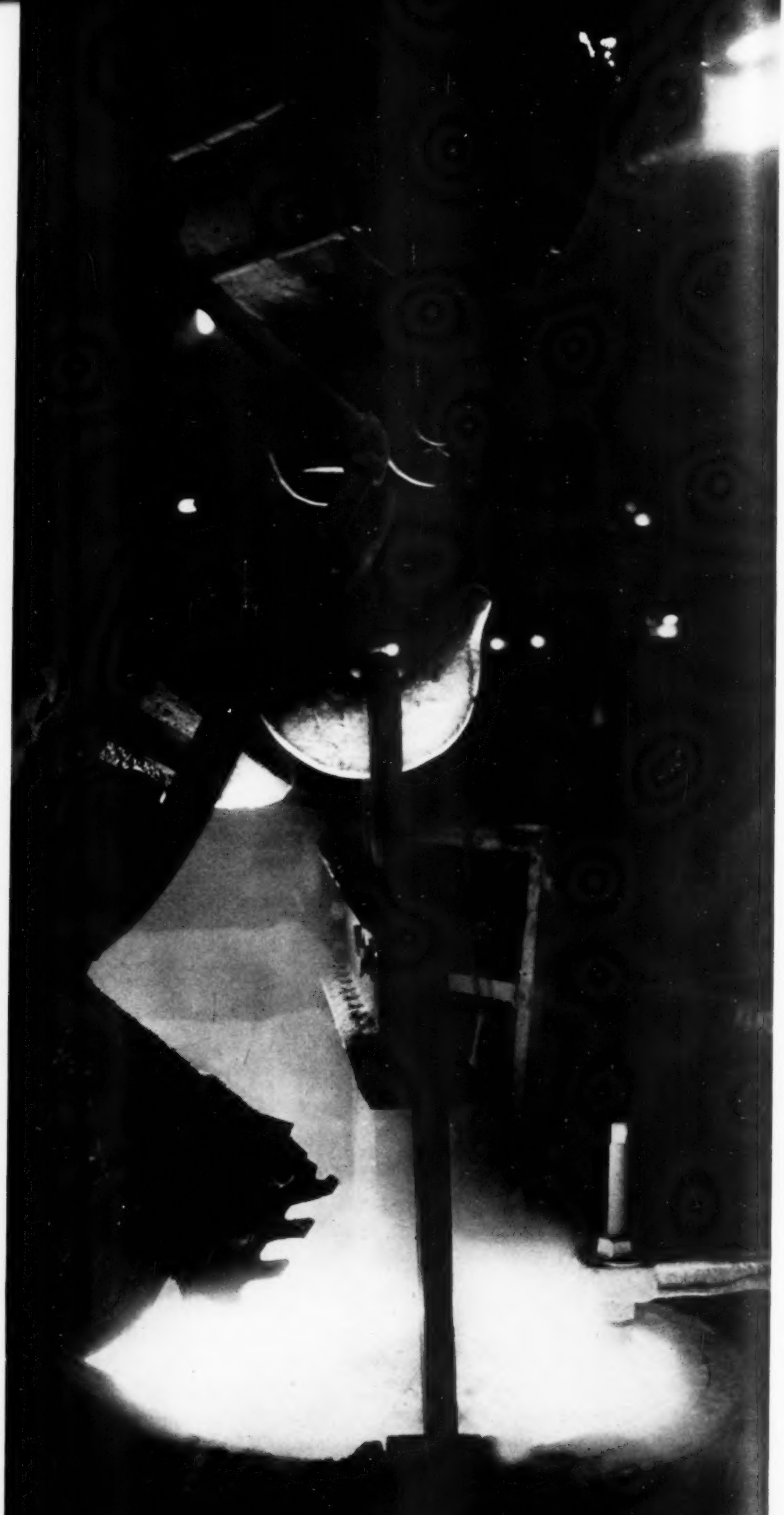
Leaded bronzes are also being made to fill a definite demand. In this paper this term means a strong alloy principally of copper, containing some tin (rather than a material for a shaft or axle bearing).

The table on this page shows the effect of lead on a machinability of "Chamet bronze." This non-leaded alloy has long been used for marine installation and other structural purposes where considerable strength is required. It always presented the difficulty of poor machinability, and this has been overcome by the addition of about 1% lead, which has not, as you will see, detracted from the physical properties to any appreciable extent. It has improved the machining qualities so much that the sale at the present time exceeds that of the original non-leaded variety.

A further demand from the industry has necessitated the production of a leaded phosphor bronze which combines many of the desirable properties of phosphor bronze with ready machinability. Tests made on a single rod are also listed in this table.

The last three columns indicate the effect of lead on commercial bronze or hardware bronze, which is a red-colored alloy used largely for ornamental work.

In conclusion, it is hoped that the data presented will help to demonstrate to users of brasses and bronzes that the presence of lead in small quantities need not be avoided in order to obtain desirable properties in copper alloys, and that the addition of this element is decidedly beneficial in improving the machining properties without detracting appreciably from other desirable qualities.



A Panel From a Series of Photographs Taken by Miss Bourke-White for Ludlum Steel Company

. . . EDITORIAL . . .

Pittsburgh Studies To Be Extended

A NOTABLE five-year research program into the science of steel making is about to be completed in Pittsburgh. It is notable for several things. A number of competing firms, Carnegie Institute of Technology, and U. S. Bureau of Mines are contributing money, men, and facilities — but it is not the first cooperative effort on record. The program was outlined five years ago, and in five years it will be completed — but it is not the first five-year plan of history. It is the most notable, and probably unique in this: That the discoveries of the investigators are put to trial in a suitable furnace at one of the cooperating plants. A laboratory finding is immediately verified on a large scale, and a theoretical conclusion tested in practice.

All these Pittsburgh studies have been focused on the solid inclusions found in acid and basic steel — their origin, nature, and method of elimination. Many problems have already been solved. As a result of these studies the routine chemist has far more precise methods of determining the amount and chemical analysis of the normal inclusions. Better yet, the steel melter has been given fundamental information on the way these inclusions form, and consequently has a new technique for their elimination. Discovery of a new and powerful deoxidizing alloy is one of the by-products of the investigation.

While the cost has been considerable, the share advanced by the cooperating firms amounts to a figure on the order of 1/25 of a cent a ton, when figured on the basis of steel produced by the entire American industry since 1926. Compare this figure with even the most conservative estimate of the value of this study to the industry, and you get merely another proof that scientific research will return its cost an untold number of times — another reason why keen business men believe that research is fundamental to the advance of any industry.

Consequently, there should be little difficulty in financing a three-year extension to the Pittsburgh program. These supplementary investigations are planned along several main lines. Knowing something about how solid inclusions get into the steel, the next step is to investigate their specific influence on the tensile properties, fatigue strength, and weldability. Next is the problem of gases in steel — inclusions that are not solid. Last is a study of the action of deoxidizers added in the ladle.

Even in these times when financial officers scrutinize every expenditure, a voucher to share the cost of such a program should be classed with insurance — something which must be authorized to provide for the future.

Oxygen as a Medicine for Sick Furnaces

IN THE PAST, most proposals and experimentation with oxygen in smelting furnaces, such as the new one noted by Mr. Öhman in the correspondence columns, have been along the line of enriching the blast by injecting a certain amount of relatively pure oxygen into the blowing engine intake (or by other appropriate methods), the philosophy being that this blast would generate a higher temperature at the focus and therefore speed reduction of the ore and the melting of the reduced iron — in other words, increase the smelting capacity of a given furnace stack.

While oxygen has been used to enrich the blast while blowing in a furnace on a cold charge, its extensive trial under operating conditions has been prevented by two main considerations: (1) The high cost of pure oxygen,

and (2) the inability of the present furnaces to take the entire heat now available in the conventional manner of running.

Even though the use of oxygen as a "food" is ruled out for the above reasons, due consideration has probably not been given to its use as a "medicine" — that is, as a standby to correct an irregularity occurring at one or two of the tuyeres. Insurance against serious irregularities is now provided largely by an excess of about 150 lb. of coke (per ton of iron produced) on the burden. With a prompt method of introducing extra heat when and where required, this surplus coke ought to be materially reduced.

Consider, for the purposes of specific example, a 300-ton furnace with 10 tuyeres taking about 2,500 cu.ft. of free air per min. at 925° F. through each tuyere. Suppose it is running cold at one tuyere (temperature of coke about 2,500° F.). The flame temperature may be computed to be 3,500° F., which is too low, as evidenced by the continued dullness at that tuyere.

If oxygen is discharged at the rate of 200 cu.ft. per min. into the normal blast going through the tuyere, the local flame temperature will be immediately increased at least 500° F., and continue as long as the extra oxygen is supplied. This fillip in temperature might easily bring the heat at the focus considerably beyond the critical point, near which it had previously been hovering, and put the dull spot in the furnace back into an active condition where it can do its share of the work.

The cost of a few cylinders of oxygen used in this way would be far more than overbalanced by the saving of one cast of off-grade iron. Furthermore, as the furnace operators become acquainted with the symptoms which can be corrected by "oxygen medicine," the amount of surplus coke could be gradually reduced.

It is surprising that the effects of this powerful reagent in homeopathic doses have not been closely studied. Oxygen is already familiar to progressive furnace men. It is always available in the cast house, ready to open a frozen iron or cinder notch. It would be natural to extend its use to doctor an ailing furnace at the tuyeres.

Who Owns Metal Progress?

LEGAL NOTICES are the dullest kind of reading for laymen — it might even be wondered whether lawyers think they are literary compositions! Nevertheless, there are times when all of us feel it is necessary to wade through masses of legal verbiage, such as an insurance policy or a lease.

A similar case in point is the statement of ownership appearing on page 143 of this issue. It is couched in such remarkable language merely to conform to the dictates of the law. This law was enacted in order that the readers of any periodical can have an opportunity of finding out the actual owners of the publication, and guiding themselves accordingly. Fulminations about the Communists within our midst, for instance, could be discounted if it appeared that the journal printing them were owned by the Children of the Revolution.

Stripped of its surplus words, the sworn statement already referred to shows that METAL PROGRESS is owned, lock, stock and barrel by The American Society for Steel Treating. No individual has any stock interest or any mortgage on it, or holds any bonds on this property, or gets any "split" in the profits.

Such a statement is a wholesome thing to broadcast, for there is a persistent rumor circulating via the grapevine telegraph that this journal is privately owned, and is merely trading on the Society's good name. All members of the A. S. S. T. who have the good of their organization at heart will do well to scotch this rumor whenever it is heard. For the Board of Directors, in voting to establish METAL PROGRESS, did so with the conviction that the Metal Congress and Exposition could not be relied upon as a safe and permanent source of the revenue (over and above the modest share of the annual dues retained by the national office) necessary to finance the ramified activities the members have come to expect. On the other hand, to quote its own words, "The Board does feel that your publications offer this security and per-

manence which are essential to the future success and activities of the organization."

Naturally the full measure of success for these publications cannot be achieved as long as any potential supporter suspects that his society is not reaping the financial surplus which rightfully belongs to it. Hence the necessity of emphasizing again and again the flat and unqualified statement: METAL PROGRESS is the official magazine, owned solely and entirely by the American Society for Steel Treating.

Credit for Promoting Structural Welding

FUSION WELDING of structural steel building skeletons, from a modest beginning four or five years ago in single-story sheds, has been extended at a marvelous rate until today an announcement of a 15-story completely welded office building would almost lack news interest. Within the last 12 months upwards of 10,000 tons of structural steel has been fabricated and erected, either in whole or in part, by this new method. It is estimated that at least 80 buildings of importance have been so constructed since the beginning, and the aggregate tonnage undoubtedly exceeds 25,000.

An article in this issue of METAL PROGRESS gives the reasons for this rapid advance and the economic factors which will modify its future progress, as seen by the manufacturing superintendent of one of the country's largest building construction companies. Some additional emphasis should be put upon the essential part played in this advance by our sister organizations, the American Welding Society and the American Bureau of Welding.

Indeed, they have done a notable work in acquiring reliable data on the properties of welded joints, and disseminating information on the proper technique of welding, the proper methods of design, inspection, and all other matters of procedure control. They have realized from the first that progress in the application of this new and economical method of construction would be measured by the rapidity with which this information could be acquired and broadcast.

Engineers, designers, and fabricators have been quick to realize that welding has great possibilities for cutting costs and saving material. Numberless small pieces and shop operations could be saved in every steel structure. The opportunities for making joints of higher efficiency and structures with smaller secondary stresses and "factors of ignorance" are obvious to them.

However, the bulk of the architects, owners, and building inspectors are conservative enough to wish to avoid experimentation. They will not grasp at a moderate saving on the total cost of a building and risk the stability of the entire investment. It required the activities of a numerous body of experts, interested in all phases of the work — such as comprise the American Welding Society — to gather the necessary information to reassure these doubters.

It is in no way casting aspersions on the very laudable efforts of manufacturers of welding machines and welding supplies to recognize that investigations made in their own laboratories will always be discounted as tinged by propaganda, and therefore fail to have the widespread influence the importance of such work demands. Hence the need of national bodies, supported by all competing interests.

In three separate directions the two organizations mentioned have performed essential services. First, they have shown how to select the welder and measure the quality of his work. That takes care of the hitherto unknown "personal equation" of the workman. Second, they have determined safe working stresses for welds in standard sections, made by qualified welders under shop conditions and supervision. That removes the guesswork from the designer's table. Third, they have adopted a code covering fusion welding and cutting in steel construction, which can be and is being written into the building laws of American cities. That protects the owner from the jerry-builder.

Truly this is a notable and essential contribution to progress.

By Robert E. Bultman
Assistant Metallurgist,
White Motor Co.

HEAT TREATING GEARS MADE OF ARMOR PLATE

MAGNIFY ten times the impacts, the stresses and the loads of the transmission gears of a passenger automobile. Add then an amount of abuse which few car owners dare give their cars. The result approximates the conditions under which the transmission and rear axle gears in a 10-ton truck must operate, and operate without fail for a life many times longer than most passenger cars.

Quantity production of such gears exacts much from the material, from the heat treatment, and from the machine tools. Steels used must be of prime quality, free from forging cracks, segregation, or other defects. The heat treatment is necessarily complex, involving annealing, hardening, carburizing, tempering, toughening. Machining is difficult because the better able a gear steel is to meet the demands of road service, the more difficult it is to cut and finish.

Experience in the manufacture of heavy trucks and busses has proved to the White Motor Co., of Cleveland, that it can have confidence in gears made from two types of steel — *(a)* 5% nickel steel, and *(b)* an alloy steel made in this country to an analysis devised at the Krupp works in Germany. (This latter steel has been much used for armor plate, because of its strength and toughness.) The White Motor Co. early recognized this steel's suitability for rear axle pinions and transmission gears, and put it into commercial production despite the added machining and heat treating costs imposed by the same characteristics which make it suitable for heavy armor. Most of the transmission gears for White trucks and busses are now cut from steel of this class.

The Krupp analysis calls for an electric furnace product with a carbon range of 0.08 to 0.16%, although the lower half of the range is preferred. Chromium in the amount of 1.20 to 1.70% is specified, the preferred range being 1.20 to 1.50%. Nickel runs between 3.80 and 4.30%, preferably between 3.80 and 4%. All steel of this class is submitted to a microscopic test on a polished and etched specimen to guarantee freedom from any defects before forgings are accepted.

All ring gears and those transmission gears not made of the Krupp analysis are of a 5%

Fast, Hot Work! Hardening the blanks from which small pinions will be cut

nickel steel corresponding to S.A.E. 2512. This is a basic open-hearth steel. The complete analysis of both steels follows:

Element	*Krupp*	*5% Nickel*
Carbon	0.08-0.16	0.08-0.16
Silicon	0.35 Max.	0.35 Max.
Manganese	0.30-0.60	0.30-0.50
Sulphur	0.025 Max.	0.040 Max.
Phosphorus	0.020 Max.	0.040 Max.
Chromium	1.20-1.70	
Nickel	3.80-4.30	4.75-5.25

Neither type of steel presents any unusual difficulties in machining after it has been properly prepared, although the speed of every operation is lower than would be observed in other gear-making plants, because of the toughness of the steels. Dimensions are closely held both in machining and heat treating, because truck buyers are as insistent upon quiet gears as sedan owners.

Heat treatment procedure contributes greatly to the service records of the gears in White trucks and may be considered the most important single phase of the manufacture.

The gears made of the Krupp steel require a more complicated heat treatment than those cut from the 5% nickel steel. Some of the armor plate gears have a tendency toward distortion after carburizing, because of the thick-and-thin sections, or of other design factors. Such gears are re-cut after carburizing and, therefore, must be heat treated four times.

Chrome-Nickel Gear Treatment

Complete heat treating procedure for these chrome-nickel gears which are re-cut is as follows:

First, the forged gear blank is quenched, from 1,550° F. in oil and then drawn to 1,200° F. They are now ready to be machined. An allowance of 0.012 to 0.015 in. over the final size is made for re-cutting.

Carburizing follows the first machining op-

Tool Set-Up for Rough Machining Cluster Gear Blanks Which Have Been Quenched and Drawn

eration. Gears are packed in pots with a carburizing compound, and held for 24 hr. in electric furnaces maintained at 1,700° F. After carburizing, the gears are quenched direct from the box into oil, unless irregularities of shape and section make cooling in the box seem more advisable.

No matter which method of cooling is followed, all are again packed, this time in spent compound, and returned to the electric furnaces for heating to 1,350° F. They are then cooled slowly in the furnaces for 72 hr., at the end of which time they have cooled to approximately 600°. Still in the boxes, the gears are kept overnight in an insulated chamber to cool to 300 or 400° F. In the morning they are taken from the boxes, sand blasted, and, if on a shaft, are straightened.

This prolonged period of slow cooling makes the gears soft in preparation for several finish-machining operations which follow. Every gear is tested and must scleroscope 38 or less, or show a maximum Brinell number of 229.

Final machining includes re-cutting 0.012 to 0.015 in. from the teeth to remove distortion, and taking finishing cuts on keyways and splines. The gears are then hardened by heating to 1,400° F. and quenching in oil. After tempering for 2 hr. at 300° F., they are cleaned or wire brushed. A second series of hardness tests (100% inspection) must show every gear file hard and measuring at least 80 scleroscope.

Case depth on finished gears varies between 1/16 and 5/64 inch.

Not all gears of the chrome-nickel analysis have to be re-cut after carburizing. Blanks for gears which are to be ground on the teeth are quenched and drawn before machining exactly like those for re-cutting. Machining operations, however, leave 0.002 to 0.003 in. for grinding. These gears are carburized an average of 16 hr. at 1,700° F., as they do not lose so much of the case in clean-up to exact size. As was described for the re-cut gears, some can be quenched from the carburizing box into oil; others must be cooled in the box.

Typical gears which can be quenched are pinions for rear axle assemblies. These are lapped rather than ground. They are hardened by quenching in oil from 1,400° F. and are tem-

pered at 300°. These gears are cut to mate with ring gears, and the mating pairs are lapped in, eliminating grinding.

Box-cooled gears are double treated to refine both the core and the case. Heating to 1,550° F. and quenching in oil takes care of the core, and reheating to 1,400 and again quenching gives a close-grained case. Gears are tempered at 300° F. before the 0.002 to 0.003 in. surplus is ground.

Obviously the heat treatment of gears made of armor plate steel calls for close scrutiny of the time and temperature factors. Machining is not too easy at best, but it would be much more difficult if the gears came through warped or otherwise distorted, or having a decarburized spot, or generally too hard. The routine just outlined makes it possible to produce hundreds of gears every day, almost identical in size and properties and all able to withstand severest service.

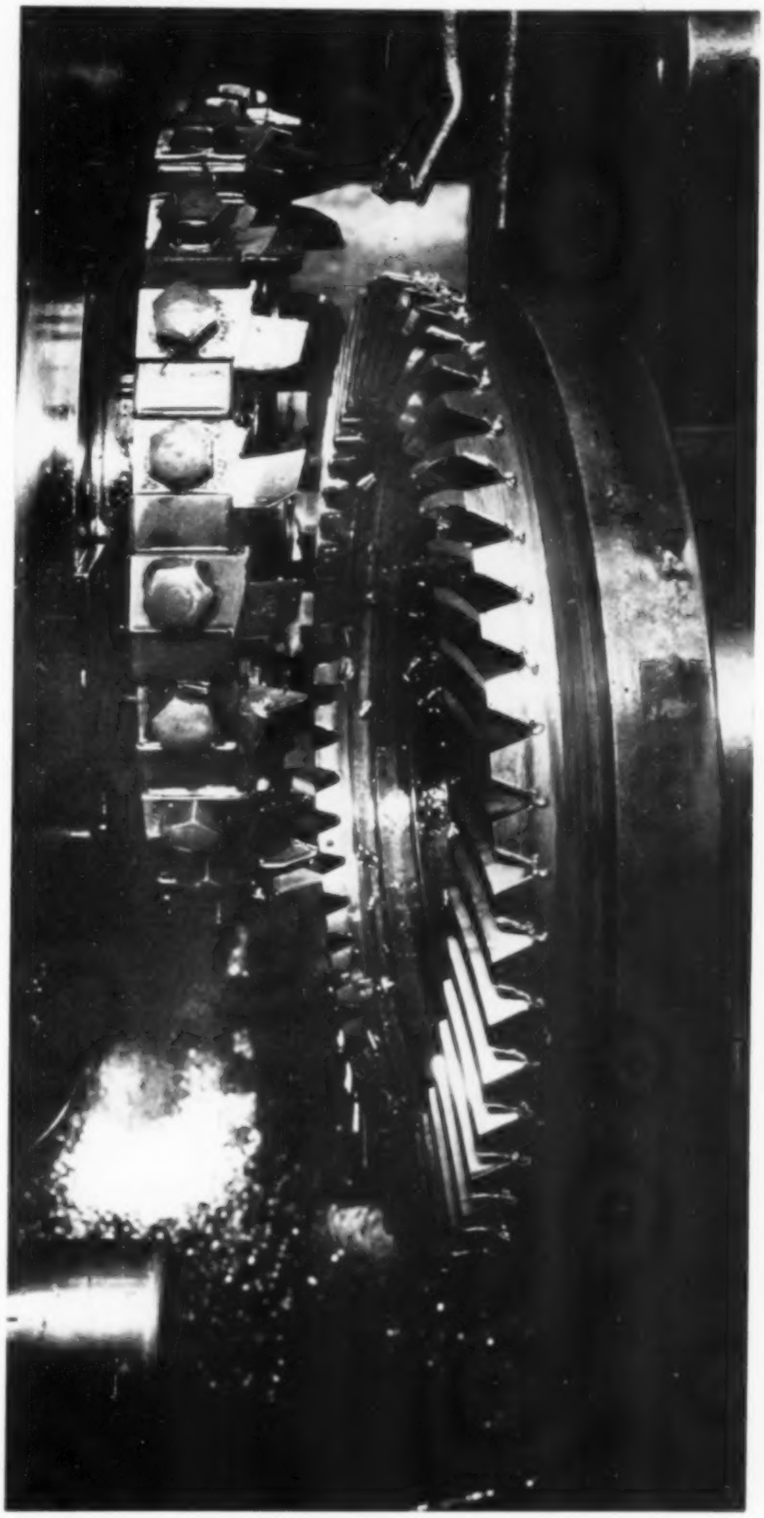
Nickel Steel Machines Easier

Ring gears and a few transmission gears are made of 5% nickel steel, which can be heat treated and machined somewhat more easily. Gears of this steel do not have to be re-cut. Some are ground after carburizing; the others are lapped.

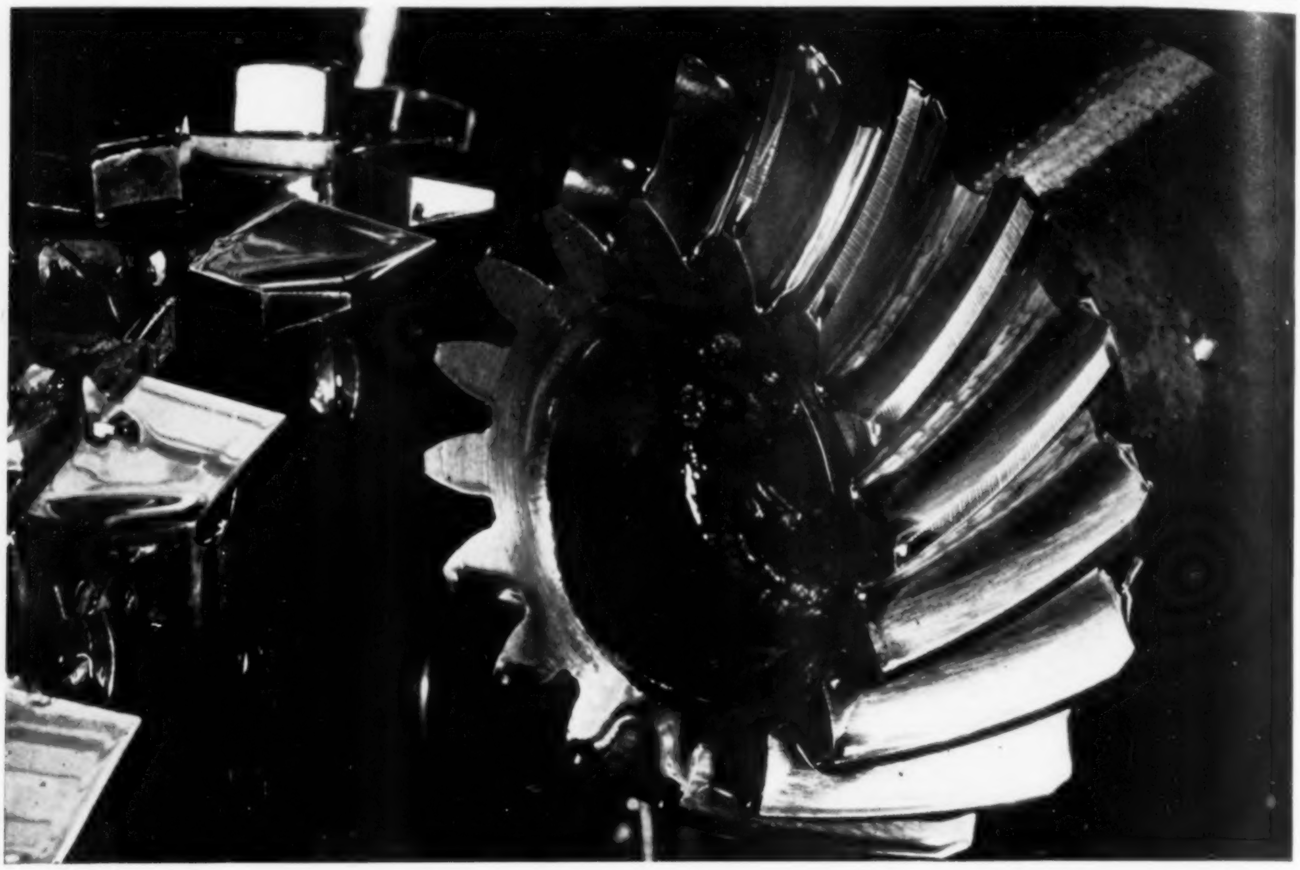
Forged gear blanks of nickel steel are heated at 1,500° F. and quenched in oil, following which they are drawn at 1,250° in an electric furnace. After tempering, the gears leave the heat treatment department temporarily for cutting and similar operations. All machining is done on the gear at this time; heat treating and grinding are then necessary before the gear is finished.

After machining, comes carburizing. A case between 1/16 and 5/64 in. thick is produced by packing 5% nickel steel gears in compound in boxes and holding them at 1,700° F. for 16 to 18 hr. The gears are then allowed to cool in the carburizing box.

To refine the case the pieces are reheated



Cutting the Teeth of a 5% Nickel Ring Gear. Machining presents no great problems despite the toughness of the material

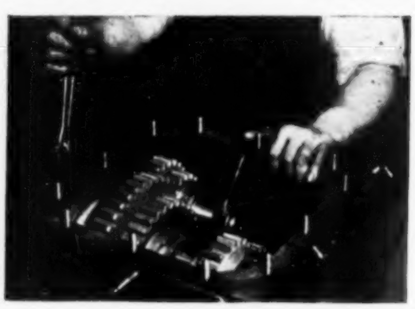


This Little Pinion Will Go Into a Rear Axle. The camera catches the gear cutting machine in a temporary respite

to 1,440° and quenched in oil. Ring gears are quenched in a Gleason machine, in order to prevent distortion. The final step in heat treatment is a 30-min. draw at 300° F.

Treated gears are then ground to size if lapping alone will not accomplish this. A scleroscope test of each gear completes the manufacturing operation and must show hardness between 80 and 90. They must also be file hard.

It has been thought proper to describe this somewhat unusual type of gear, since metallurgical friends have sometimes doubted the necessity of using these high-alloy steels. However, we have uniformly found that when another gear or another analysis, said to be "just as good," is installed in our test trucks and subjected to the brutal treatment that only these drivers know how to give, the substitute gears have broken down or shown excessive wear in a relatively short time.



The Final Transmission Assembly. Finishing touches are being put on the gear box of a big truck

And yet strength is not the only quality which truck and bus transmission gears must have. Quietness in operation is also demanded, especially by bus operators. A well designed gear, accurately machined, must not fall below their high standards, because of an inferior heat treatment.

Truck and bus-fleet owners are prone to wonder if the manufacturer is attempting to cheapen his car if something goes wrong when the speedometer shows 250,000 miles. Consequently we have found it good economy to instal nothing but the toughest and hardest gears we know how to produce.

EVIDENCE THAT METAL IS CRYSTALLINE

By E. E. Thum

A GREAT MANY of the conclusions reached by the study of metallography depend upon the assumption that solid metal is a crystalline substance. The evidence supporting this fundamental proposition might well be presented, for many times metal (such as wrought iron) tears apart with a fracture which suggests the fiber in wood more than anything else; in fact, a "fibrous fracture" is supposed to indicate the greatest toughness in metal. Furthermore, it might be unreasonable to postulate essential similarity in crystalline structure of the ductile metals like iron (which can be easily forged at almost any temperature,) and brittle ones like bismuth (which cannot be forged under any circumstance). Furthermore, it is natural to think of crystalline materials as being substances like salt and massive limestone, which break up into perfect geometric solids. In fact, pieces of metal which break in service and show a bright fiery fracture are popularly said to have "crystallized" in service and hence become weak and brittle. This is an apparent contradiction in ideas; how can a crystalline metal be tough? Or conversely, how can tough wrought iron be crystalline?

Before getting far into this question it is necessary to define the essentials of crystallinity. What is the difference between a crystal and an amorphous body?

If a crystal of alum is broken (even ground up) and the fine particles examined under the microscope, they will be found to have definite facets and edges having the same angular relations as the original piece. Since there is no apparent limit to this subdivision, the metallographist defines the crystalline state not so much with reference to the outer form of the substance as to the orderly geometric arrangement in space of the atoms themselves. It is this location of the atoms in rows and ranks and on parallel planes which is responsible for the regular outer form of the perfectly shaped crystal, and for its cleavages.

Outer form is accidental; inner structure is necessary. As a matter of fact, crystals with good outer form may only be produced under special conditions where nothing interferes with perfect growth. Most rocks are made of crystalline minerals, but the constituent grains, called crystallites, interfere with each other's growth, and when they are picked out of the mass their

Dendrite in a Cavity in 0.62% Carbon Steel. Enlarged 10 times. Photographed by V. N. Krivobok of Carnegie Institute of Technology

external form is rough and irregular, despite the perfect symmetry of atomic arrangement, shown by a regular system of cleavage planes when the material is broken.

That steel has an essentially crystalline structure may be inferred from the fact that fir-tree forms, or "dendrites," quite regular in shape, are sometimes found projecting from the walls of large pipes in a slowly cooled ingot. Likewise, if the crust of a partly solidified ladle of bismuth is broken and the liquid drained off, the cavity will contain very large crystals looking like nests of cubical boxes.

Long crystals of pure tungsten, with sides slightly fluted, may be made in a curious manner. Inside a glass bulb, containing only a small amount of chlorine gas, are two tungsten filaments—one straight one, like a spider thread; another a large coil of commercial wire. The coil is heated to 1000° C. by passing an electric current through; the chlorine attacks this and forms platinum chloride, a gas. The gas breaks down on reaching the straight filament, maintained hotter, at 2000° C. Atom by atom is thus transported, and atom by atom a long square crystal, perfect in outer form, is built!

These are a few of the instances where metal has a regular outer form characteristic of a crystal. Inner form is shown by ingots of brittle metals like antimony and zinc. When broken the fragments have surfaces which are bounded by flat planes, irregular in extent, but suggesting an extremely orderly arrangement of the ultimate particles throughout sizeable

Below Is a Ladle Skull; Crystals of Pure Bismuth Have Grown Inward. About quarter size. At left is side view and end view (fracture) of single crystal tungsten. Enlarged 2 and 4 times, respectively. Photographed by W. P. Sykes of Cleveland Wire Works

Slice of Meteorite Found at Kingston, N. M., Showing So-Called Widmanstatten Structure. From American Museum of Natural History

portions of the mass.

Likewise, if a meteorite (a falling star is frequently found to be an alloy of iron and nickel) is cut and polished, beautifully regular markings appear which can be explained only on the assumption that the meteorite is a big crystal.

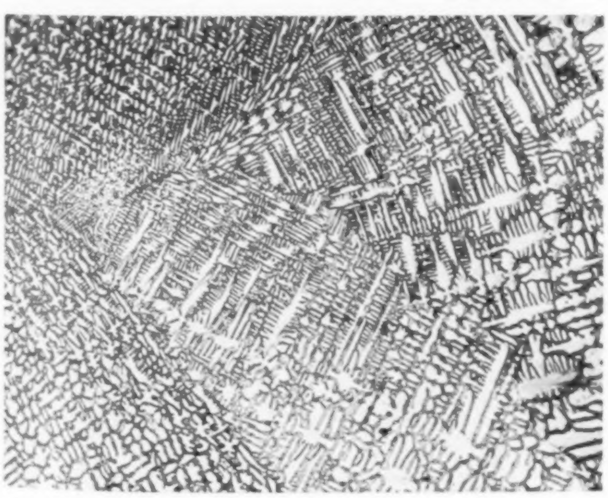
Another instance of regular internal structure is that from slowly cooled steel ingots, somewhat high in phosphorus. When sectioned and etched with Heyn's reagent they show a structure of interlocking ferns called dendrites, the main stems and branches of which follow geometric patterns suggesting that the metal atoms have a systematic arrangement which has been defined as the crystalline state.

More evidence to the same point follows: Dendrites rivaling in beauty the frost crystals on the window in winter, are formed on the surface of the star antimony of commerce. Spangles of zinc on the surface of galvanized sheets are also very suggestive of the essential crystallinity of metal.

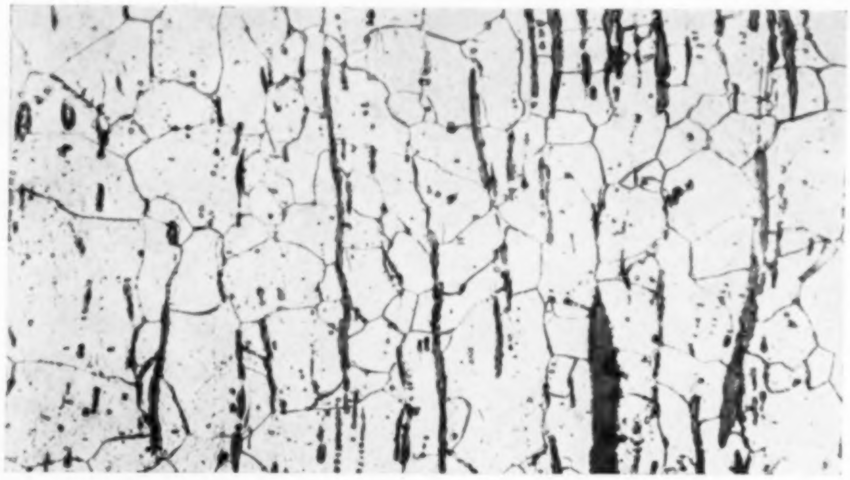
Nature of Microscopic Grains

Such evidence may be seen with the naked eye; but in most metals the individual grains or crystallites are so small they cannot be seen except under the microscope. Thus, in a polished and etched specimen of wrought iron the boundaries of the individual grains of iron are eaten into slightly by the etching reagent. The roughly polyhedral contours do not have any systematic or definite geometric form. Since these contours are the intersections between the surface of the granules and the plane of polish, it is apparent that the granules must have a form much like a water-worn pebble. The question, however, as pointed out above, is not one of external form so much as internal arrangement. Are these grains crystalline?

A slightly deeper etching on a polished sur-



Dendrites in Casting of Copper-Cobalt Alloy. Photographed by J. R. Vilella of Union Carbide & Carbon Research Laboratories



Wrought Iron, Slightly Etched, Showing Slag Streaks and Grain Boundaries of Iron Crystallites. Magnified 100 diameters. Photographed by E. P. Best of A. M. Byers Co.

face of pure metal will give some supporting evidence. Each grain acquires a slightly different tone, different from its neighbors, but uniform within its own boundaries. This indicates uniformity *within* the grain, and agrees with the assumption that each may be a crystal, but each one is tilted or "oriented" slightly differently; that is to say, the polished plane intersects the principal axis of each crystal at a different angle.

Deeper etching will sometimes develop well-defined etching pits. These are of similar shape and have parallel edges, each to each, within the boundaries of a single grain; little crystalline fragments have evidently been eaten away. Etching pits are also consistent with the explanation advanced in the preceding paragraph.

More evidence of orderly arrangement of atoms in metal is seen in individual grains in brass which show characteristic markings called twins — narrow and broad strips, uniform in width, crossing from boundary to boundary, parallel each to each within each grain, but at random angles when one grain is compared with another. Such markings could only be spontaneously and systematically developed in a material which has a regular internal arrangement.

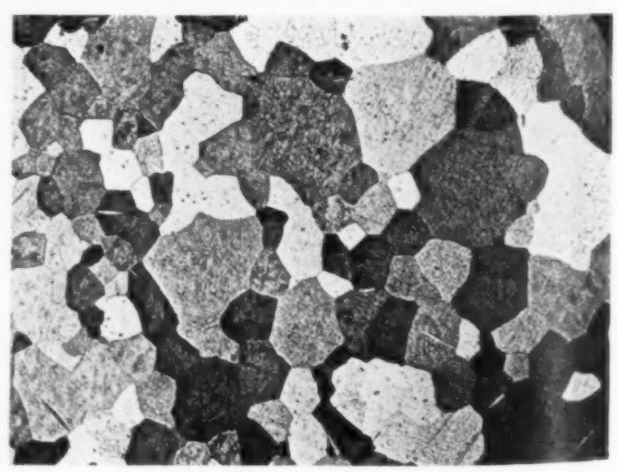
Other grains which are perfectly mirror-like and without apparent structure may, by appropriate heat treatment, develop so-called martensitic markings which group themselves parallel to three or more principal directions in each grain, but these directions change from grain to grain — more evidence of an orderly ultimate arrangement of the atoms which compose each grain of metal.

As a matter of fact, it is not necessary to confine the evidence to brittle metals. Ductile metals can deform without breaking, and when they deform they produce "slip bands" across the grains formerly developed by polishing and etching. Slip bands are also evidence of crystallinity.

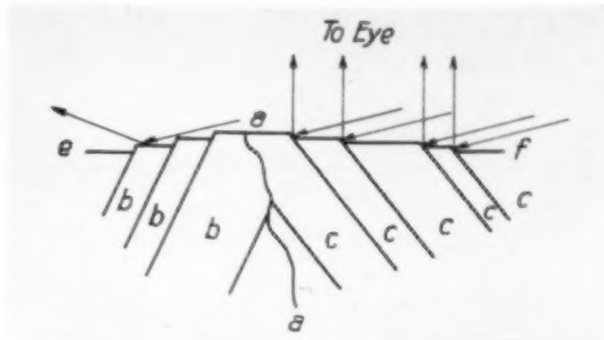
If a polished, slightly etched strip of pure iron be bent beyond the elastic limit, it will be found that the surface is marked by straight lines, limited in extent by the grain boundaries, and the markings in each grain are parallel to each other. Furthermore, if the specimen is examined under oblique light at the correct angle, the markings in a single grain will flash out as brilliant strips of light.

These facts are in accord with the supposition sketched in the figure (which represents a

Pure Tin, Annealed 2 Hr. at 150° C., and Air Cooled. Magnified 100 diameters. Photographed by J. R. Vilella of Union Carbide & Carbon Research Laboratories



Stress Beyond Elastic Limit Breaks Metallic Crystals Into Blocks Which Slip Slightly One Past Another



section cut at right angles to the original polished surface $e — f$). Overstraining breaks the individual crystals with abutting grain boundaries $a — a$ into separate blocks b, b, b and c, c, c, which slide past each other slightly, and then freeze together again. Oblique light rays would make the slip planes in a single crystal flash out simultaneously.

Another evidence is found in the phenomenon known as grain growth. If a piece of cold worked metal is reheated to a proper temperature the old grain boundaries entirely vanish and are replaced by a new set of small grains, the average size of which usually increases with the time or temperature of the anneal. While the outer boundaries of the grains seem to take a fortuitous course, the definite relationship between average size, time and temperature can be explained only on the basis that the atomic arrangement *within* the crystal boundaries is regular.

A very large grain, grown to such a size that it includes much of the specimen, breaks in a characteristic way, along definite planes within the boundaries of the single crystal. If there were no orderly internal arrangement of atoms in such a piece, the fracture would be a warped, cupped or spherical surface — at least it would not follow parallel systems of geometric plane surfaces.

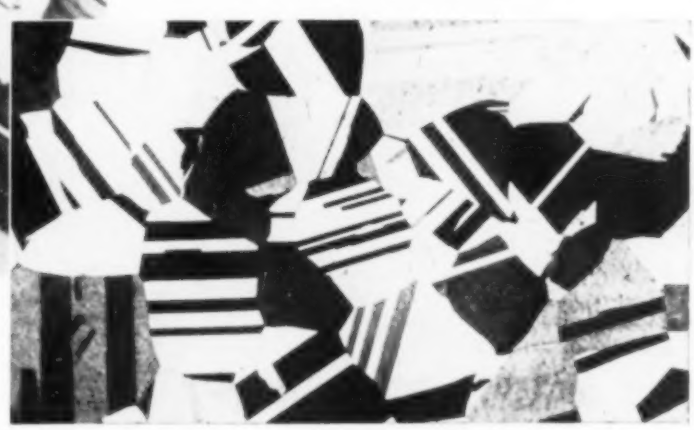
Recent X-Ray Studies

These evidences about the inner structure of pure ingot metals and in the tiny grains of wrought alloys are further supported by recent and numerous X-ray studies.

X-rays are similar to light rays in that both consist of energy radiating by impulses from a source. The closeness with which each impulse follows the other is called the wave length. The wave length of the X-ray is much shorter than the wave length of light.

Twinned Grains in Cartridge Brass After Annealing at 750 C. Magnified 75 diameters. Photographed in the Technical Department of the American Brass Co.

At Left: Three-Dimension Photography at High Powers (3,500 Diameters). A piece of Hadfield's manganese steel, water toughened and drawn at 750 C. Photographed by F. F. Lucas, Bell Telephone Laboratories



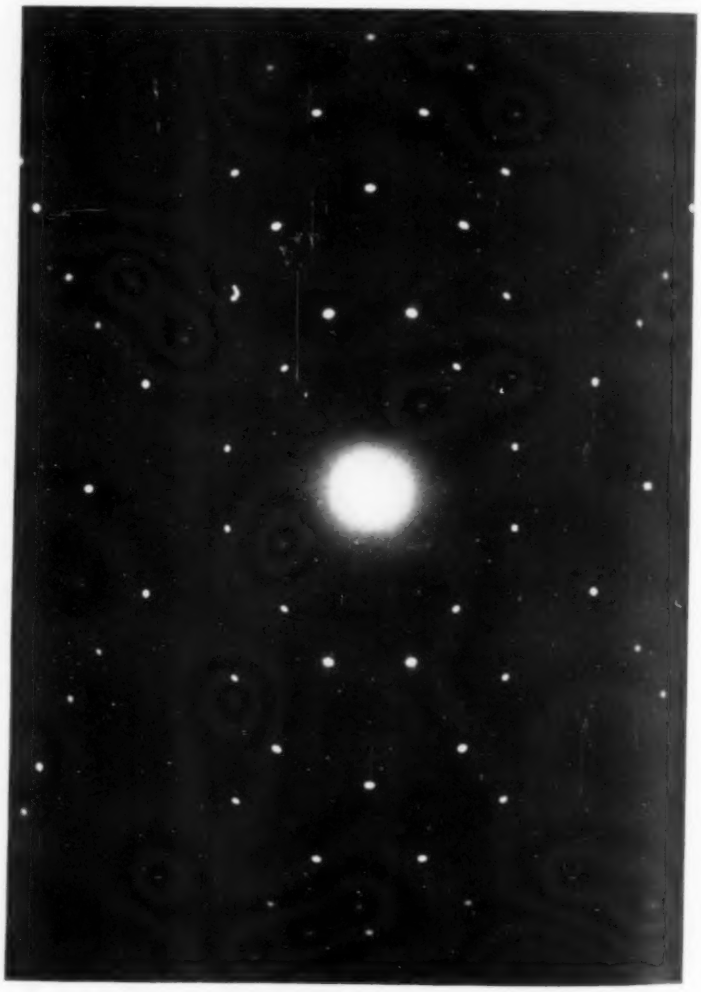
Fracture in Coarse Grained Silicon Steel. (Made by W. E. Ruder of General Electric Co.)

If a street lamp is seen through a window screen, the brilliant center appears to have four bright rays of light extending at right angles.

This is caused by the reflections from every wire which is so placed as to throw light back into the eye. The geometric pattern is caused by the geometric arrangement of the wires. Given such a light pattern and the location of the light and the observer's eye, the mathematician could figure out the weave and spacing of the wires in the screen.

It so happens that the wave length of X-rays is shorter than the distance between atoms (hence its ability to penetrate solids). Consequently, it was argued that if the atoms of a crystal were arranged in a definite geometric pattern, then an X-ray beam penetrating the crystal would be reflected in definite ways and emerge in a geometric pattern. In fact, a mathematician is able to predict the exact pattern which would emerge if the atoms of a crystal were arranged (for instance) like a pyramid of cannon balls.

When the experiment was tried, such an exact pattern was produced! This is proof positive that the tiny grains composing a metal sample are crystals, despite their irregular outer shape.

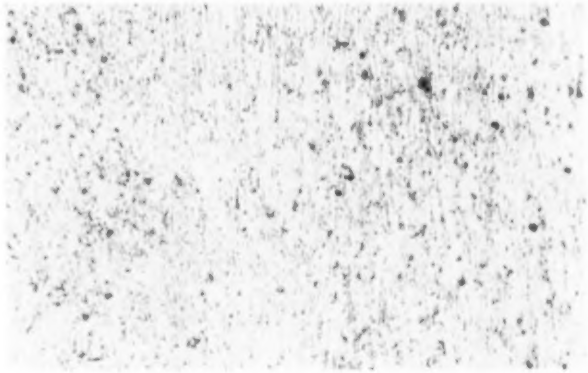


X-Ray Pattern Produced by Single Grain of Silicon Steel. Made by G. L. Clark of University of Illinois

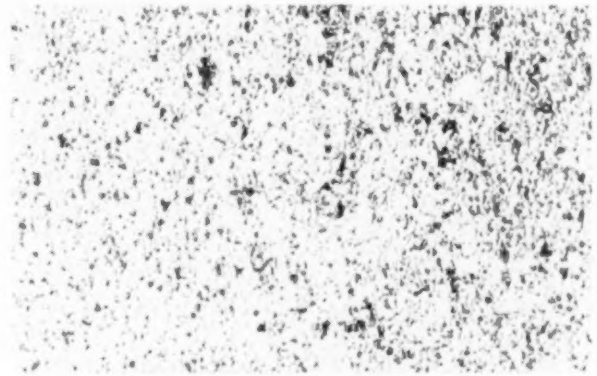
Early Stages in the Recrystallization of Chromium-Iron

Metcalf Test on 0.0375-In. Strip, Heated 20 Min. and Quenched. All Micros 150 Diameters

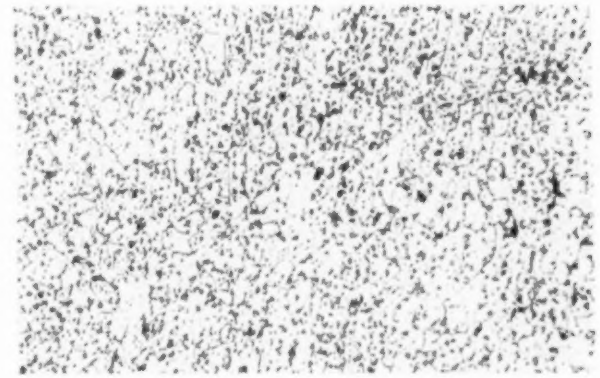
Analysis: Carbon 0.07, Chromium 16.14, Manganese 0.33, Silicon 0.96, Copper 0.07



Original Hot-Rolled Structure of Thin Strip. Distorted and elongated grains of chromium-iron alpha solution with stringy areas rich in carbide. 92-B hard.

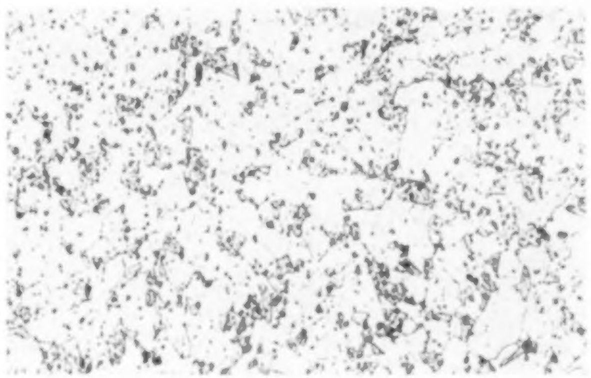


First Evidence of Breakdown of Carbide Areas. Rockwell 68-B.

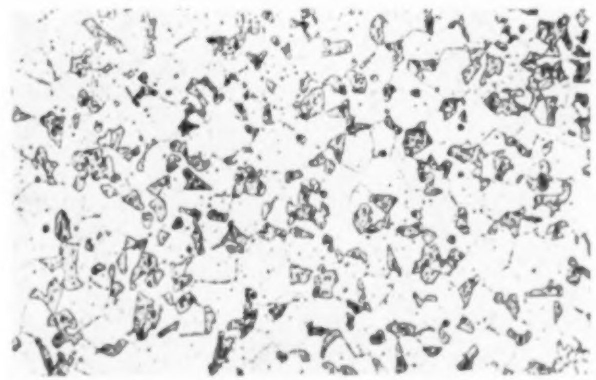


Chromium-Iron Alpha Solution Now Completely Equi-Axed. Small martensite patches and some carbide particles uniformly distributed. Rockwell 68-B.

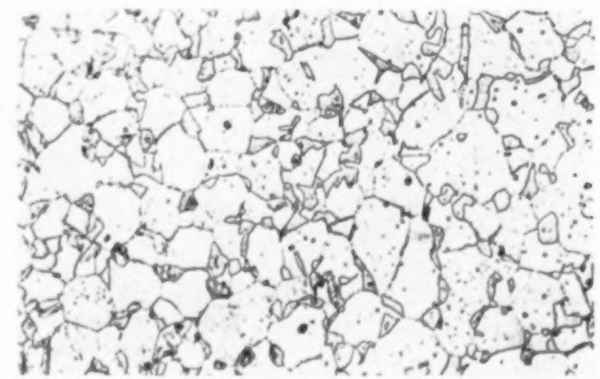
First Stage: Equi-Axing of Grain and Dispersion of Carbide



Alpha Grains Increase in Size. Patches of austenite have formed, mainly at grain boundaries, and have been preserved by the quench, partly transformed to martensite. 83-B hard.



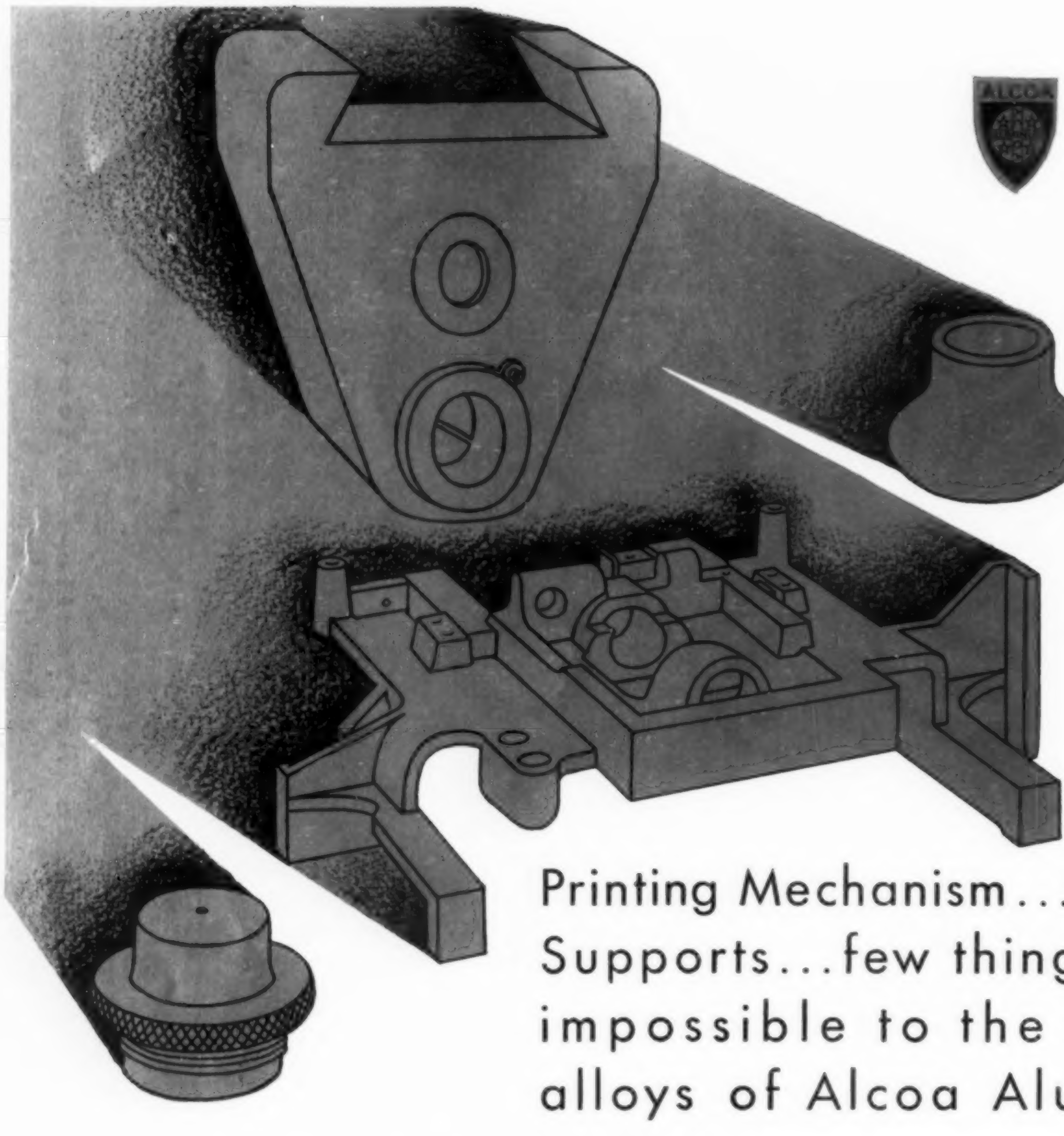
Average Grain Size Still Larger. Carbide particles have been entirely absorbed in solid solution, and therefore the austenite-martensite patches or grains have become more definite and larger in size. Rockwell 88-B.



Alpha Grains of Chromium-Iron Solid Solution Increase Slowly In Average Size, But Austenite-Martensite Grains Occupy Slightly Larger Proportion of Volume. Rockwell 92-B.

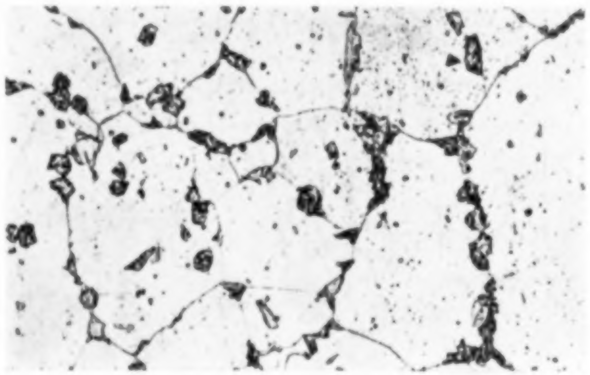
Second Stage: Formation of Definite Austenite-Martensite Grains

Photomicrographs by C. C. Snyder, Republic Steel Corporation

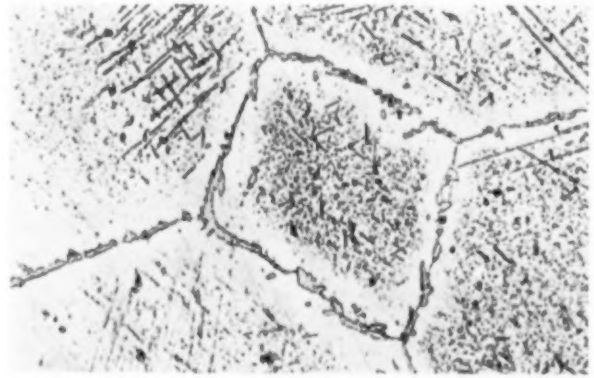


Late Stages in the Recrystallization of 16% Chromium-Iron

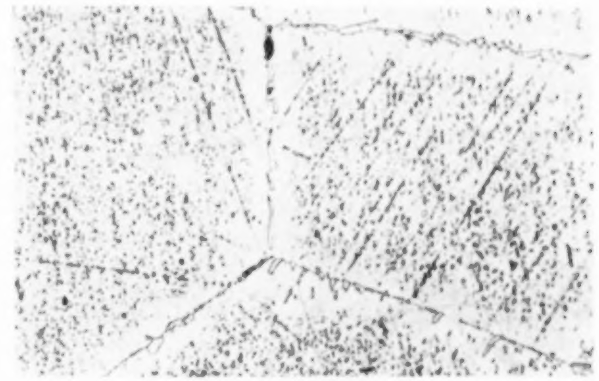
Metcalf Test; Maximum Temperature 2400° F. All Micros 150 Diameters



Marked Increase in Alpha Grain Size at Expense of High-Carbon Austenite-Martensite Patches at Boundaries. Some grains slightly cloudy at centers. Rockwell 93-B.

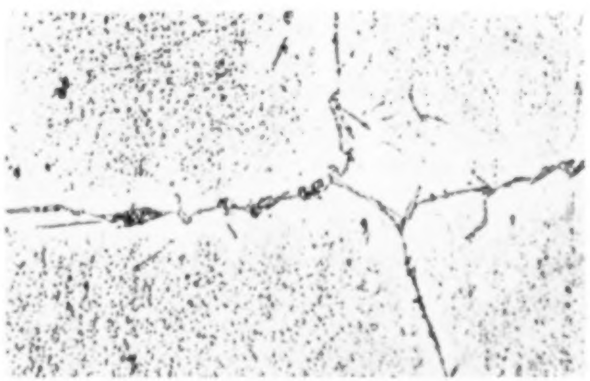


Another Tremendous Increase in Grain Size. Grains now have austenitic films surrounding them, casings of a clear solution, and cores of austenite-martensite. Rockwell 98-B.

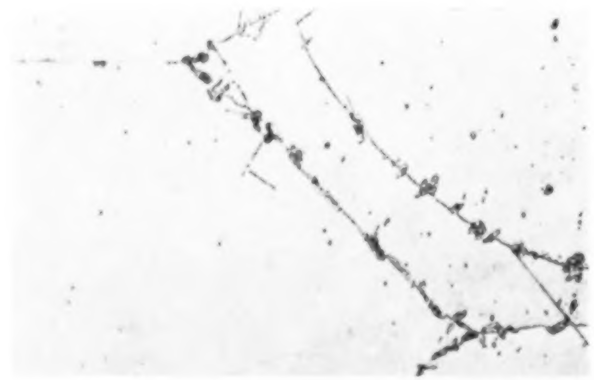


Further Increase in Grain Size. On higher magnification the cores are resolved into small spheroids, dispersed in clear matrix or attached to needle markings. 103-B hard.

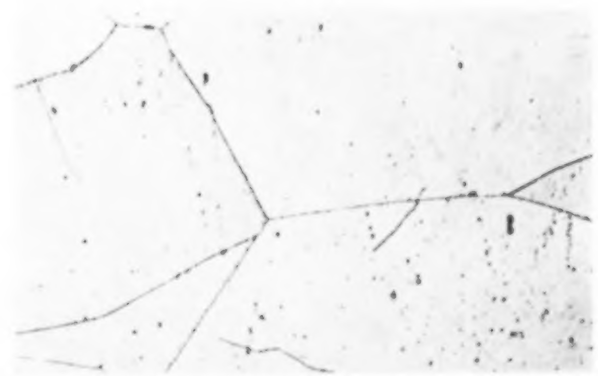
Third Stage: Extremely Rapid Growth of a Composite Grain



Last Stage of Absorption of Excess Constituent Into Solid Solution in the Cores of the Grains. Rockwell 99-B.



Last Stage of Absorption of Excess Constituent Into the Surface of Alpha-Delta Grains. Rockwell 96-B.



Almost Pure Alpha-Delta Iron. Temperature of this spot before water quench was 2400° F. Rockwell 89-B.

Last Stage: Entrance of Carbide Into Solid Solution

Photomicrographs by C. C. Snyder, Republic Steel Corporation

CORRESPONDENCE . .

. . AND FOREIGN LETTERS

Expansion of Italian Plants for Aluminum

THE FIRST of the three new plants for the production of aluminum erected in Italy during the last three years belongs to the Società Alluminio Veneto, Anonima (S.A.V.A.) and is located at Porto Marghera, near Venice.

Porto Marghera, where the new industrial center for Venice is under development, occupies about 4,000 acres of level ground, in which has been dug a complete system of canals admitting the largest ocean carriers. This system of canals, connected with a complete railway system, puts the whole industrial area in direct communication with the commercial port of Venice and with the Adriatic, so that the numerous industrial plants now there or being erected are given the greatest facilities for receiving the raw materials and for shipping their products, both abroad by sea and to nearby points by rail.

On a parcel of this ground covering about 80 acres, S.A.V.A. started the erection of the new plant in 1928 for the production of aluminum. The first two units of this plant have been in regular operation since 1929, producing 6,000 tons of metal annually. The necessary power is produced by the same company in a new hydro-electric power station located about 60 miles from Porto Marghera on the Cissmon River.

The principal raw material is supplied by large deposits of excellent bauxite belonging to the same company and located near Albona on the Adriatic coast. Bauxite is shipped to the works by sea at a very low cost.

In addition to these plants, the company owns an electrode factory at Bussi (Abruzzi) and a plant at the same place for the production of alumina, using bauxite from another deposit located nearby. The capacity of the works will shortly be considerably increased.

A second aluminum plant belongs to the Società Italiana dell'Aluminio, a subsidiary company of "Montecatini." (The latter is a powerful concern, practically controlling the Italian production of fertilizers, and owning a great number of works scattered all over Italy for the production of super-phosphates and synthetic ammonia.)

Works of the Società Italiana dell'Aluminio are located at Mori (Trentino), adjoining its hydro-electric power station which produces the direct current used for the electrolysis. The alumina treated in the Mori works is produced in a plant belonging to another subsidiary located in Porto Marghera, not far from the works of the S.A.V.A. company mentioned above.

In this plant the bauxite, coming by sea from Istria, is treated according to the new Haglund process. A mixture of bauxite, pyrite, and coal is melted in an electric furnace, producing a liquid layer of aluminum sulphide containing the alumina in solution, floating above the residual mass, which contains the iron and the other impurities. The upper layer is easily separated from the rest of the melt, and, after cooling, is treated with hot water, which decomposes the aluminum sulphide, giving aluminum hydroxide and hydrogen sulphide. Aluminum oxide and hydroxide, so obtained, are submitted to further processes of purification (especially magnetic, in order to eliminate the iron

completely) and are finally electrolyzed in the ordinary furnaces.

This group of "Montecatini" plants has also an annual capacity of 6,000 tons of aluminum.

Finally, the third new plant for the production of aluminum is now under construction, and the first unit of it will be in operation before July. These works, planned on a much larger scale than the other two, will use lava rock as raw material. Huge deposits of this exist in central Italy, in the region included between Orvieto and Naples. The most conservative survey of only a part of these deposits shows at least one billion tons of lava rock, containing 300 million tons of leucite, analysing 16.5% K_2O and 22% Al_2O_3. The reserves here amount to about 33 million tons of aluminum.

Leucite crystals are to be separated from the basaltic magma in which they are contained by taking advantage of their magnetic properties. They are then treated with nitric acid, which dissolves all the alumina and potassium, leaving a strongly reactive silica gel, a commercial by-product. The solution of nitrates is treated with more nitric acid, in order to precipitate the nitrate of aluminum, which is then separated and decomposed at high temperature, giving aluminum oxide and nitrogen oxides. These last are converted to acid and re-used in the cycle of reactions. From the remaining solution the potassium nitrate is finally obtained, a valuable product for the fertilizer, chemical and explosive industry.

The new plant is located near Civitavecchia, on a plot of about 1,200 acres. The first unit (now nearly ready for operation, and having an annual capacity of about 2,000 tons of aluminum) will be followed immediately by others now under erection.

It results, therefore, that the present production of aluminum in Italy, amounting to 12,000 tons annually, will be augmented to 14,000 tons by midsummer. The industry is also preparing a further expansion, as the needs of home industry and foreign trade require.

Federico Giolitti

Turin, Italy

New Method of Speeding Nitriding

Variations of stress at high frequency have a very singular effect on steel, according to a note presented by M. Mahoux to the French Academy of Sciences. Test pieces, mechanically connected to a steel plate which was vibrated by an electro-magnetic oscillator, became highly reactive to their surroundings and more susceptible to subsequent heat treatment.

For instance, a nickel - chromium - molybdenum steel, placed 9 hr. in an ammonia current at a temperature of 500° C. and under the influence of high frequency oscillators, was nitrided to a depth of 0.35 mm. and to a surface hardness of 1,033 Vickers. In the same conditions and for the same metal, but without the influence of the oscillations, no measurable increase in the surface hardness was observed, and the penetration of nitrogen was an insignificant amount (about 0.01 mm.).

On the other hand, a gray pig iron submitted for 10 hr. to the influence of high frequency vibrations in air at 530° C. became covered with sooty carbon deposit and was decarburized to a depth of 0.08 mm.

In both cases the high frequency vibrations seem to provoke a migration of nitrogen and carbon in steel. Another fact is still more curious. A mild steel test piece plated with chromium and submitted to the influence of high frequency oscillations for 9 hr. at 530° C. was said to have shown under the microscope a chromium penetration 0.35 mm. deep. Nickel, electrodeposited on the surface of the steel, is also absorbed by the latter when the temperature reaches 450° C.

Lastly, steels submitted to the influence of these vibrations, and then heat treated, had their properties materially improved over those which would ordinarily be expected.

These vibrations might thus be a new factor whereby physico-chemical reactions may be accelerated, either by increasing their speed at a temperature where they act too slowly, or by

lowering the temperature at which they begin to be apparent.

Such high frequency vibrations would therefore act in the same direction as an increase in temperature, which has formerly been the pre-eminent means of decreasing the passive chemical resistances, and of speeding the reactions. In this relation, it should be remembered that elevated temperature increases the atomic or molecular agitation in the reacting substances and that these vibrations decrease the passive resistances.

If further study of the influence of this new factor confirms M. Mahoux's anticipations, and specifies the experimental conditions (such as the vibration frequency to be used under particular circumstances), a wide field of research will open for both metallurgist and chemist.

ALBERT PORTEVIN

Paris, France

Oxygen-CO Blast for Iron Furnace

BESIDES the unusual purity of the iron ores of central Sweden, the main factor contributing to the high quality of Swedish steel is the use of charcoal instead of coke in the blast furnaces. On account of this fuel, the phosphorus and sulphur content of Swedish pig iron are almost entirely decided by the analysis of the ore. These factors, combined with the inherited skill of the workmen, gave to Swedish wrought iron and steel (in older times) an almost unique position.

Modern developments in the steel-making processes, whereby high quality steel may also be made from less excellent raw materials, have confronted the Swedish steel makers with serious economic problems. To make the competitive situation worse, our costs have risen. While the price of charcoal has always been fairly high, the appreciation during the last 20 years has been considerable.

It is therefore only natural that the steel industry has tried its utmost to reduce the charcoal consumption to the lowest possible figure. A very considerable step in this direction followed the invention of the electric blast furnace, about 1910. In the ordinary blast furnace the fuel acts both as a reducing agent and as a source of the necessary heat for smelting, while the latter function is taken over by electric energy in the electric blast furnace. The charcoal consumption in the latter is only about 40% of that in the ordinary blast furnace.

Although the pig iron produced in electric furnaces is of the same high quality as that obtained in the more conventional furnaces, this invention has not proved to be a cure-all for the Swedish steel industry because the process can compete only if the price of electric energy is extremely low. Sweden has enormous resources of water power, but this is not available to all Swedish steel works at a sufficiently low price.

At present, electric pig iron is produced by only two big companies, the Uddeholm and the Stora Kopparbergs Bergslag, which are both fortunate enough to own big waterfalls, enormous forests, and iron mines in convenient proximity. Nevertheless, electric pig iron in Sweden is about 17% of the total output.

As was reported by Dr. Westgren in METAL PROGRESS last October (page 104), a considerable amount of experimenting has been done during the last few years on a cheap method of producing iron sponge to be used for making open-hearth steel in place of scrap, of which there is a serious shortage. Another attack on the problem of cheaper pig iron has been made by A. Grönwall and H. Nathorst, who have patented a new method of iron smelting, which they believe should decrease both the charcoal and scrap consumption of our industry. Either pig iron could be produced by this process with only about 55% of the charcoal consumed in the ordinary blast furnace, or an impure steel would be the result, which could afterwards be refined in an electric or open-hearth furnace.

The main principle of this new method is to blow into the ordinary blast furnace a mixture of about one volume of oxygen and eight volumes of carbon monoxide. The gas mix-

ture burns the charcoal, produces CO with some CO_2, passes up through the shaft, reduces the ore to metal, and sufficiently preheats the overburden of ore and charcoal.

When the gas mixture has left the furnace and been cleaned of dust, CO_2 is absorbed, and the remaining carbon monoxide is mixed with more oxygen and blown into the furnace again. The quantity of CO_2 absorbed is equivalent to the sum of the oxygen added to the circulating gas stream plus that reduced from the ore; the circulating gas volume is thus kept constant.

Estimates of operating costs show that the electric power required for this process would stand a much higher price than the power necessary for smelting in the electric blast furnace.

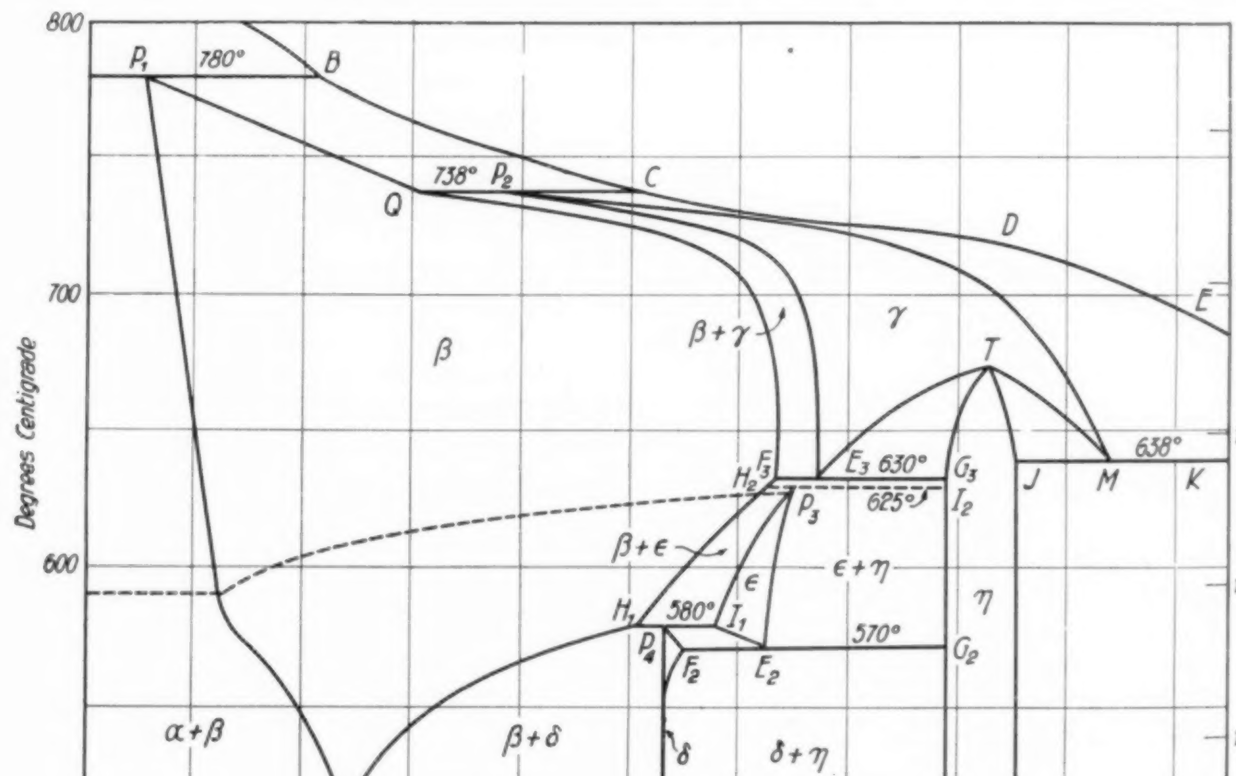
EINAR ÖHMAN

Stockholm, Sweden

Compounds In the Cu-Sn and Other Systems

THE EQUILIBRIUM diagram of copper-tin alloys, and especially the structure of alloys containing 10 to 40% of tin, is still open to question; in fact, many structures which are scarcely explainable by any existing diagram may be obtained by heat treatment. The latest diagram is probably that of Raper, who has certainly made a step forward in the solution of this problem.

Professor M. Hamasumi and Mr. S. Nishigori have studied the same subject in Japan for the last two years, and have obtained a diagram which is different in some important points from those hitherto obtained. Alloys in the range of 25 to 40% tin are very brittle and can hardly be made



Portion of the Equilibrium Diagram of the Copper-Tin System

into rods, the form of which is necessary for the measurement of electric resistance and thermal expansion (both very powerful methods of detecting changes in structural phases). However, these investigators succeeded in obtaining specimens in rod form by special methods, which for lack of space cannot be mentioned here. Besides these physical methods of study, thermal analysis and microscopic observations were also made, to the end that the equilibrium diagram of copper containing up to 45% tin was revised as shown in an annexed figure.

There are two intermetallic compounds, δ and η corresponding to $Cu_{31}Sn_8$ and Cu_3Sn respectively. The compound δ, formerly considered to have the formula Cu_4Sn, is proven by these workers to have a composition corresponding to the formula $Cu_{31}Sn_8$, which fact has already been pointed out by Westgren. The compound η changes at 675° to a solid solution γ.

Three eutectoid transformations at 508°, 570°, and 630° corresponding to equilibrium reactions $\alpha + \delta \rightleftarrows \beta$, $\delta + \eta \rightleftarrows \epsilon$, and $\beta + \eta \rightleftarrows \gamma$, and two peritectoid transformations at 580° and 625° corresponding to $\beta + \epsilon \rightleftarrows \delta$ and $\beta + \eta \rightleftarrows \epsilon$, are found. The existence of the new phase ϵ is also confirmed by microscopic examination of the quenched specimens.

Another matter of great scientific importance has to do with the heat of mixture in molten metals.

Numerous investigations of the heat of mixture for aqueous solutions and organic liquids have been made, but those dealing with metals are very meager. To fill this gap in our knowledge, Dr. M. Kawakami has been studying the heat of mixture for numerous binary alloys. In five years he has investigated as many as 41 alloy systems.

His method uses a high temperature calorimeter in which two metals, previously melted in separate vessels and brought to a common temperature, were mixed together in definite proportions. The change of temperature caused by the alloying action was measured.

Some general conclusions obtained from this multitude of measurements are as follows:

1. In the class of binary alloys which do not form any intermetallic compounds, the heat of mixture is negative, with the exception of some bismuth alloys.

2. For the class of alloy systems having one or more intermetallic compounds, the heat of mixture is positive, and very large as compared with Case I.

These facts lead to the important conclusion that an intermetallic compound, which exists in solid phase up to the liquidus of the equilibrium diagram, does not decompose into its components during melting, but exists as such in the liquid phase, certainly to the temperatures of the melts used by Dr. Kawakami.

KOTARO HONDA

Sendai, Japan

Hardness of Steel Changes With Its Age

IT HAS long been known to practical men in the metal industry that a slow increase in hardness often takes place in the finished product, especially wire and sheet, after it has been placed in warehouse. Considerable trouble has often been experienced on this account, but an explanation of the phenomenon, and thereby a means for preventing its occurrence, has been very slow in forthcoming.

Toward the end of 1928 Dr. G. Masing gave a lecture before the Verein Deutscher Eisenhüttenleute on "The Improvement of Alloys, and New Experiments on the Aging of Iron." He offered a theoretical explanation of aging and in the last two or three years extensive research work has been conducted in Germany to investigate this theory. A good insight has thus been had into the old trouble, and entirely new possibilities realized for an improvement in the quality of many grades of steel. A fault may thus be converted into a virtue.

Masing's theory applies to the influence of minute quantities of alloying elements on the hardness of steel. It was probably suggested by the theories explaining the hardening of dura-

lumin; what is new is the extension of these ideas to the realm of steel.

A short review of the prevailing theories on the cause of hardness may be desirable at this juncture.

Hardness may be described as "ability to resist penetration," or, which is the same, "ability to withstand forces tending to change the form of a piece of metal." If there is a strong resistance to any change in form, the metal will be hard; if the metal changes its form under applied stress fairly easily, it will be soft.

Any and all metals are built up of crystalline grains, but the internal flow occurring in somewhat soft and ductile metal under stress beyond the elastic limit does not take place along the grain boundaries but along slip planes within the crystals. If slip along these planes can be hindered or prevented, a harder metal will be obtained.

Resistance to slip obviously depends on the nature of the metal; that is to say, on the structure of the atom, and the magnitude of the interatomic forces (a matter about which we know all too little). It also is influenced by the presence, on these slip planes, of foreign particles that act as "keys," and thus prevent the intercrystalline flow in the metal which would otherwise occur. Hardness of hardened tool steel is, for instance, due to the precipitation of cementite particles on the slip planes during hardening, so that internal flow is effectively blocked, and thus the typical hard but brittle material is obtained. By tempering, the cementite gradually wanders toward the grain boundaries; the metal is softened because the intercrystalline flow is facilitated by removing the keys.

Perhaps the above constitutes a too-simplified view of the cause of hardness in metals, and there are a number of other factors that undoubtedly are of importance, but this version will serve to explain Dr. Masing's new theories. These are simply that slip-preventing keys can be formed (and thereby an increase in hardness) under favorable conditions by a number of alloying elements, added purposely or not, and in such small quantities that they often are considered as impurities.

With an increase in hardness, a corresponding change in physical properties (such as tensile strength) is also obtained. A change in hardness of low carbon steel of almost 100%, with an almost equal increase in tensile strength, has been purposely achieved in carefully conducted experiments. In the writer's personal experience, cold drawn, high carbon chromium wire has been known to increase in hardness from 225 to 265 Brinell in the course of a few weeks' storage at ordinary warehouse temperatures. This increase is hardness was most decidedly unwanted, and the result was rather disastrous on the tools when trying to use the wire for cold heading purposes.

These phenomena are explained by an inter-crystalline precipitation of minute foreign bodies in the matrix of the crystalline grains. However, this precipitation is not sudden, as when hardening tool steels, but takes place over a period of time extending from a few hours up to a month, depending on the element that is causing the gain in hardness, and on the method of heat treatment.

A number of alloying elements are able to cause this aging phenomenon in steel, the main ones being carbon, oxygen, nitrogen, copper, and beryllium. It should be mentioned that this action of carbon is entirely separate and independent of that portion of the element present in steel as pearlite or as pearlite + cementite in hyper-eutectoid steel. The kind of hardness here under discussion is caused by the minute part of carbon that is soluble in iron at temperatures lower than the critical point. About 0.02% carbon is soluble in ferrite at room temperature, as is clearly shown in the iron-carbon equilibrium diagram published in METAL PROGRESS, Sept. 1930, page 81.

CORRESPONDENCE AND FOREIGN LETTERS

The properties in common for all alloying elements capable of an age-hardening action of this kind are that they are able to be absorbed in a solid solution in iron and that their solubility increases with the temperature. If one or several of the above-mentioned elements are present in the steel, a definite amount corresponding to the temperature will have gone into solution at any temperature, say, between 400° and 900° C. Attention is called to the fact that this temperature range corresponds to the majority of annealing and hot working operations.

If the metal is cooled slowly from the elevated temperature, there will be a gradual precipitation of the foreign elements (as the solubility decreases with the sinking temperature). The alloying element will then be precipitated as more or less complex chemical compounds with iron. If the cooling is slow enough, these will migrate to the grain boundaries, and when so located they have little influence on the hardness of the steel. Their actual presence in slowly cooled steels can be observed under the microscope.

If, however, the cooling takes place more rapidly, the alloying element is not immediately precipitated, but remains in solid solution at the lower temperature. Their actual presence in the iron crystal can be proved and has been carefully studied by means of X-ray analysis. The foreign element is, however, not truly soluble in the ferrite, and in the course of time it separates or precipitates in the matrix of the crystals. A migration to the grain boundaries is impossible at the low temperature where this precipitation takes place. The precipitation product therefore remains within the body of the crystals, there forming minute keys that prevent movement along the slip planes of the crystals when under stress.

This precipitation will take place at room temperature, but can be hurried by means of tempering. The most effective temperature range is 50° to 100° C. If a higher temperature is employed, say, 150° to 200° C., the precipitation is accompanied by a migration to the grain boundaries, where their possible influence on the hardness of the metallic alloy is lost. It is possible to follow the gradual development of this process under the microscope, which fact places this theory on a solid basis.

In a hardening process of this kind there is, of course, a wide variation in the increase of hardness, depending upon the conditions.

For a given chemical composition, the maximum hardness increase is obtained from a high quenching temperature and a rapid speed of quench. This should be self-evident, as at a higher temperature a large amount of the alloying element goes into solution, and at a high cooling speed the soluble part is more completely preserved in a dispersed condition within the crystals than if the cooling speed is slow. A faster quench, however, is not necessary for obtaining results, and there is no doubt that the air cooling so prevalent in steel manufacture is often quite fast enough to develope the aging phenomenon at a later time. The required speed of cooling is, moreover, dependent on the element or the combination of elements causing the hardness.

The above is an attempt to give in a very short and simplified form the theory behind this precipitation hardening ("Ausscheidungshärten," as it is called in Germany). There are, of course, many angles to this question that cannot be covered in detail in a short letter, and the literature on this subject is already quite large.

This new theory is one of the most interesting proposed in the metallurgical world in the last two or three years, and in a forthcoming letter will be discussed some of the results already achieved by its application, as well as its future possibilities.

E. W. Ehn

Cannstatt, Germany

MIRRORS AND REFLECTORS all use metal

EVER SINCE Narcissus became fascinated with his reflection in a pool, mirrors have been associated with legend, superstition, and ritual. Chinese history is particularly rich in mirror lore, and beautiful specimens of magic mirrors made of bronze inlaid with gold or of solid silver inlaid with iron are preserved.

The common superstition of the bad luck caused by breaking a mirror can be traced back to the power attributed to a mirror of warding off evil spirits by reflecting them and forcing them to take earthly form. In certain districts mirrors are still hung on bed curtains for this purpose. Another interesting superstition was this: Ground-up mirror metal taken as medicine would assist the doctor by lighting up the patient's insides!

Chinese have used metal mirrors not only as charms and as looking-glasses, however, but also for such utilitarian purposes as for kindling fires by collecting the rays of the sun in concave mirrors, and for reflecting and increasing light and sound.

Most persons, when mirrors are mentioned, think only of the glass of which they are made, without considering that it is only a backing of metal which makes the mirror possible. Although silvered glass is used for most ordinary purposes, metallic reflectors have a wide commercial application.

For 2,000 years mirrors were made entirely of metal — bronze, copper, iron, silver, and gold. Today bronze mirrors are still used for lamp reflectors, while many of the newer alloys, such as stainless steel, duralumin, and stellite, are being used for the same purpose. The unbreakable mirrors in our modern vanity cases are bits of polished steel; metals are used for pyrometer mirrors and for naval and military purposes where the common silvered glass would be highly impractical.

Narcissus' earliest reflector, a pool of clear water, was superseded early in history by more convenient, man-made mirrors. It was a short step from a bowl of water to a disk of slate, which, when wet, had excellent reflecting power, and possessed the added advantage that it could be hung on the wall.

Then came the Bronze Age and metal mirrors. Earliest evidences of bronze mirrors in both Egypt and China date them about the seventh or eighth century B. C., but there is reason to believe that they were in use long before this. The earliest Egyptian mirrors were of pure beaten copper, the handle-shanks were either hammered out in one piece with the disk, or

riveted on. When it was discovered that copper and tin could be melted together to form a stronger alloy, cast mirrors of bronze were made. When polished, these gave an excellent reflection. Other metals, such as iron and beaten gold and silver were used, but did not become so common as the half-copper, half-tin alloy. Chinese mirrors were cast in concrete molds and were polished with quicksilver. Some views are shown of the highly ornamented mirror-backs made by Chinese workmen over a thousand years ago (the property of Cleveland Museum of Art).

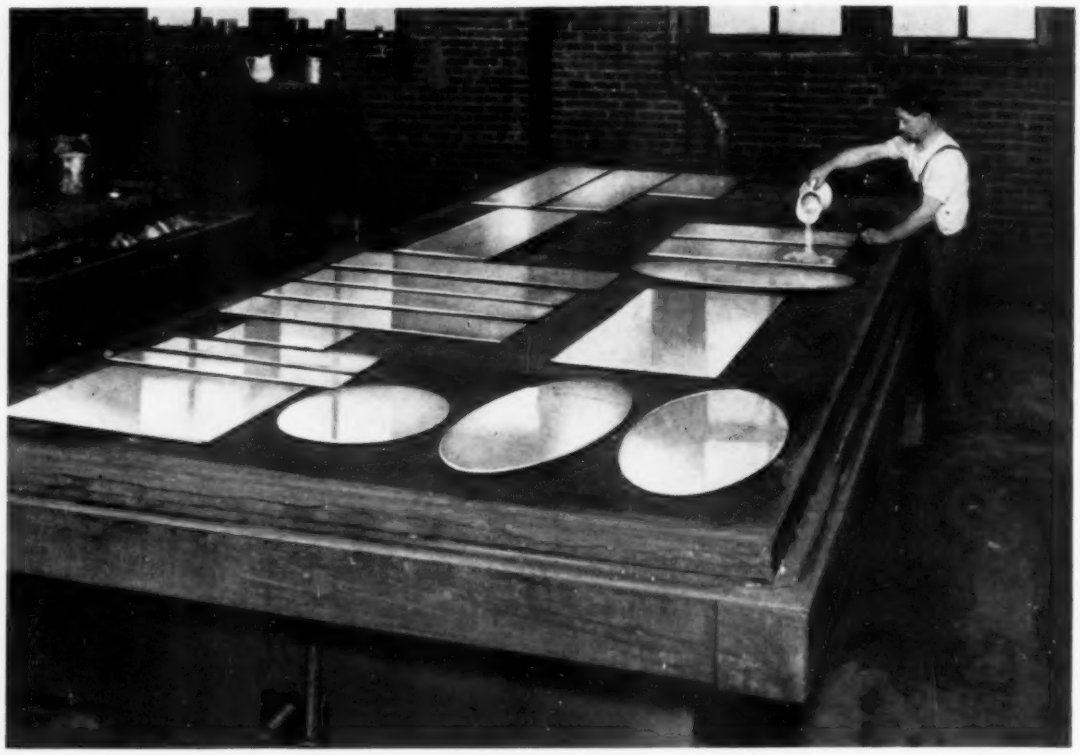
It was not until about 1300 that silvered glass took the place of bronze, iron, silver, and steel for reflecting surfaces. Although glass was known and used prior to this, it was not sufficiently transparent to replace metal satisfactorily. Glass mirrors were first made in Venice —and Venetian glass is still prized as being superior to that made elsewhere.

Mirrors were not silvered then as they are now, but were made to reflect by means of a tin amalgam backing. A sheet of tinfoil was spread smoothly on a marble-topped silvering table and covered with mercury evenly distributed by means of a woolen cloth. Excess mercury was added and the glass laid upon the amalgam. It was then covered with woolen cloths held on by iron weights which pressed out the excess mercury. The table was so constructed that it could be inclined to drain off the unamalgamated mercury. The whole process required about four weeks and was not only long and tedious but also caused injury to the silverer by exposure to mercury fumes and was costly because of the large amount of mercury used. The mirror so produced is more durable than the silver-backed type, but cannot be resilvered since the mercury affects the glass, making it rough.

In 1836 the German chemist, Liebig, invented the method of precipitating a metallic silver coating, but this process was not used commercially until 1860. There are several variations of the process but they are all substantially the same, depending upon the precipitation of silver from silver nitrate by means of a sugar solution, tartaric acid, Rochelle salts, or formaldehyde.

When sugar is used as a precipitant, the method is known as Brashear's process. It produces a hard, brilliant surface which will take a high polish and is used for large mirrors in reflecting telescopes. It is not applicable to the

Bronze Mirrors Made in China, 1,300 Years Ago, Had Backs Highly Decorated. These are about 7 in. diameter and 1/4 in. thick



Carefully Cleaned Glass Is Wedged Perfectly Flat and Covered With Silver Solution and Reducing Agent. Metallic silver precipitates and fixes itself to the glass, forming a continuous reflecting surface

commercial production of ordinary mirrors. Small optical parts of high precision are also made by this method, since other processes are carried on at a temperature high enough to affect the curvature of the glass.

Commercial mirror manufacturers use the tartaric acid and Rochelle salt processes almost exclusively. The latter is said to produce a mirror with a slightly yellowish cast, which is, however, indistinguishable to an untrained eye.

The tartaric acid process was observed in use both at Cleveland Window Glass & Door Co. and American Mirror & Art Glass Co. of Cleveland, Ohio. Only the best grade of glass is used, since a slight defect will distort the image reflected by the mirror.

After cutting the glass to correct size and shape, polishing, and smoothing or beveling the edges, the surface to be silvered is carefully inspected and marked for defects. Slight scratches, stains, and grease spots are removed on a felt polishing wheel. Blocking is done by placing the glass on a felt-covered table and rubbing it with a felt block (6 or 8 in. in diameter) and rouge. It is then ready to go to the silvering room.

Every precaution is taken to insure absolute cleanliness of the surface to be silvered. The glass is placed on a wooden rack and scrubbed with tap water, rinsed with a solution of tin chloride, washed, and rinsed again with tin chloride. This is said to cause the silver to stick to the glass, but the chemistry of the action remains a mystery of the silvering process. Final rinsing is with distilled water. (Impurities or dissolved salts would seriously interfere with a homogeneous silver deposit.)

From this time on, the glass is touched only on the under side, since perspiration from the hands will also affect the reaction. The floors of the silvering room are oiled to prevent dust from settling on the mirror, while canvas canopies suspended from the ceiling protect the silvering and drying tables.

The silvering table is heated by steam to a temperature of 90 to 100° F. The one used at Cleveland Window Glass & Door Co. is padded; at American Mirror & Art Glass Co. it is covered with a wooden lattice and serves as draining and drying table as well. Silver ni-

trate is dissolved in ammonia and water, and combined with the reducing or tartaric acid solution just before using. C. P. chemicals are used, the solutions filtered, and the porcelain pitchers in which they are mixed cleaned twice a day with nitric acid.

As the silverer pours the solution on the glass, he inserts wedges under the mirror wherever necessary to level it. A layer of solution 1/8 to 1/4 in. thick can be poured on the glass without running over the edge. It is an interesting fact that a surface of 8 sq. ft. can hold 2 quarts of solution in this way.

Precipitation of metal starts immediately and continues for half an hour to an hour, depending on the temperature, at the end of which time the deposit appears pale yellow in color. The excess solution (which protected the silver from oxidation during precipitation) is then drained off and shipped to a refinery. As much as $100 worth of silver may be recovered from one tubful.

The mirror is patted with a chamois skin to remove excess moisture and allowed to dry thoroughly on a steam table before being shellacked. In some cases the shellac is omitted for the sake of economy, but mirrors so made are less durable. The final step is the application of a coat of special mirror-back paint. This is a gutta percha paint which makes a tough elastic backing. It contains no oils which would attack the silver. Fine camel's-hair brushes are used for the shellac and paint to avoid any possibility of scratching the metal.

The process is relatively inexpensive, since 1 lb. of silver nitrate is sufficient to silver 1,000 sq. ft. of glass. Old mirrors are easily resilvered by the same method after the old backing has been removed in hydrochloric acid tanks.

Silvered balls used for garden ornaments are made by filling a large, round, glass flask successively with tin chloride, silvering solution, lacquer, and paint, and pouring it out again leaving the proper film. Curved mirrors are made in the same way. Bent mirrors, such as are used in amusement park funny houses, are silvered by "rolling," or constantly raising and lowering the glass while it is being silvered so as to get a uniform coat. Small lenses are covered by immersing in a pitcher or pan of solution and wiping off one side.

A recent improvement in mirror manufacture is the substitution of copper plating for mirror-back paint. This paint, especially in damp climates, is subject to slow corrosion and deterioration, while a metal backing is more resistant and lasting. A special process must be used in making such a copper deposit, since owing to the affinity of silver and copper, they tend to form an alloy which destroys the reflecting surface. Because of their imperviousness to moisture, such mirrors have a wide application in barber and beauty shops, in damp climates, and for marine use.

Surface-silvered mirrors 100 in. diameter for astronomical telescopes are made by the Brashear process. Those installed in the Mt. Wilson Observatory, Pasadena, Calif., must be unmounted and resilvered every six months. The mirror is lowered into a pit just below the telescope and a band with sluiceway and wooden gate is fastened tightly around it. The old silver is first removed with acid and the surface scrubbed with cotton swabs on the ends of long sticks. When the glass is clean, the reducing or sugar solution is poured on the glass and then the silver nitrate solution. The mixture is stirred constantly during the precipitation, which takes about half an hour. The gate is then opened, the spent solution run off through the sluiceway, and the band removed. The surface is dried with chamois skin and again thoroughly scrubbed. The silver film is then rubbed for from one to three hours, depending upon the quality of the deposit, with a pad of clean cotton 3 ft. in diameter, and is finally polished with a chamois pad charged with rouge. The process is carried on at a temperature approximating 68° F.

Astronomical mirrors were formerly made of speculum metal, which is a copper-tin alloy of varying proportions containing arsenic, antimony, or zinc to make it white and brilliant. However, it reflects less light than silvered glass and is difficult to cast in large sizes because of cooling strains and consequent imperfections in the surface.

A few mirrors have been made in sizes up to 18 in. of stainless steel, stellite, and invar. Difficulty was encountered, however, in polishing these metals to the very exact optical surface required. A recent development in telescope

mirrors is the use of fused quartz, which promises to become quite popular in the future.

Many different metals have been used satisfactorily in the manufacture of reflectors for automobile and locomotive headlights, searchlights, and theater floodlights. Reflectors of aluminum, duralumin, stainless steel, some silicon steels, and stellite are made by pressing or stamping the metal to the required shape, usually a parabola.

A durable and very efficient headlight reflector is made by electroplating silver on brass. The reflectors are stamped from sheet brass and drawn. Three drawings are required for large mirrors over 11 in. diameter. The reflectors are buffed with tripoli and cleaned with a commercial metal cleaner. They then move on a conveyor through a soda ash cleaning solution, cyanide dip, and nickel solution. A nickel deposit between the brass and silver increases the durability and reflectivity and prevents the silver from turning dark. After another cyanide dip the reflectors proceed to the silver plating bath, where they remain for 50 to 60 sec. Finally they are rinsed in hot and cold water, dried, and buffed with soft flannel using lampblack mixed with kerosene.

An important application of metal mirrors is in radiation pyrometers, for they must be unaffected by dust, water vapor, chemical fumes, and heat. Speculum metal and silver tarnish quickly in this atmosphere. Gold, when polished, reflects 98 to 99% of the heat rays falling on it, and pyrometer mirrors have been made by plating gold on bronze, but the coatings so formed were too thin to withstand cleaning. Nickel alloys and stainless steel have been investigated for this purpose and are found to have several advantages:

1. They are unbreakable under ordinary conditions of use
2. They tarnish less readily than other metals
3. They are harder and tougher and therefore more easily cleaned and polished
4. They show no variation in reflectivity for colored light.

Platinized mirrors are sometimes used for pyrometry as well as for dentists' instruments and other delicate pieces, since they can be obtained in very thin sections. The glass is coated with a thin film of a solution of platinum salts and bismuth chloride in collodion and industrial spirits, and placed in a furnace where the platinum is burned into the surface of the glass. The reflective film so produced is not only very thin but is at the same time impervious to moisture and chemical attack.

It may therefore be seen that the early metal mirrors have many modern counterparts which utilize various steels and non-ferrous metals. Even the cheapest glass mirrors depend upon a film of the semi-precious metal silver for the reflective power.

The Highest Achievement in Mirror Manufacturing Is the 100-in. Mirror of the Hooker Telescope at Mount Wilson Observatory. It must be re-silvered semi-annually

REVIEWS OF . .

RECENT PATENTS

by NELSON LITTELL

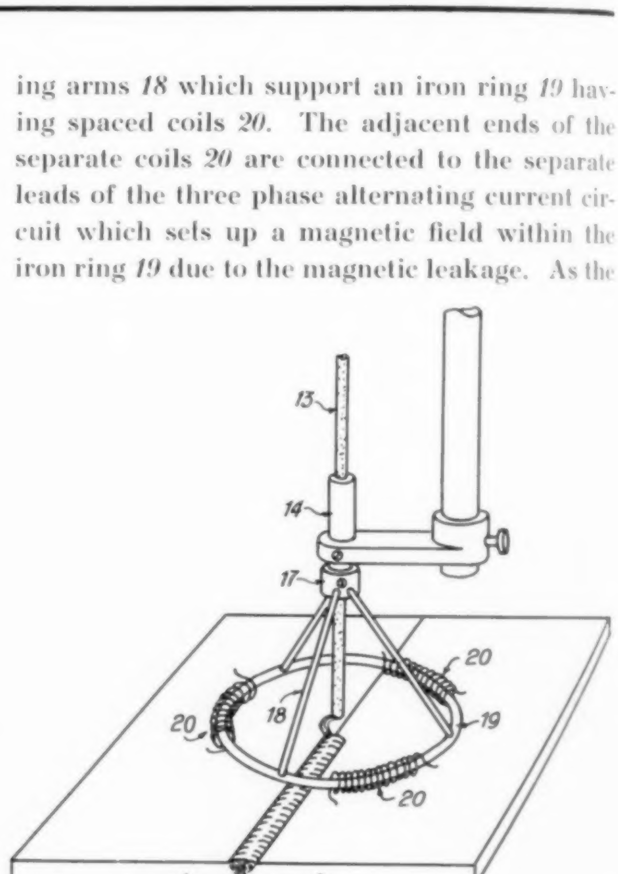
Patent Attorney | **475 Fifth Avenue** | **Member of A.S.S.T.**

Alloying Process, *by William H. Smith, Detroit. 1,793,757; Feb. 24.*

By this process finely divided metallic iron is combined with other metals and elements under temperature and pressure but without melting the iron. Sponge iron, produced by the separation of oxygen from iron ore without melting is used. Such iron is open in its atomic form. The finely divided metallic iron is associated with the alloying elements in accordance with the quality and strength of the alloy desired. The iron and associated minerals are then placed under pressure at a temperature sufficient to fuse the alloy metal but lower than the melting point of the iron. As the iron is in the open or porous form the metal of lower melting point will wet, impregnate and alloy with the porous iron whereby the iron will be evenly and completely saturated by the metal forming the alloy. The pressure closes in all the grains to a solid uniform mass of final shape and size.

Electric Welding Apparatus, *by Walther Richter, Milwaukee, assignor to A. O. Smith Corp., Milwaukee. 1,792,243; Feb. 10.*

This invention relates to an improvement in the apparatus for electric arc welding. The numerals *10* and *11* indicate two thick metal plates, the square abutting ends of which are to be welded together. The post *12* depends from the usual welding head which controls the feeding rate of the weld rod *13*. Secured upon the lower end of the eye piece *14* which guides the welding wire is a collar *17* having downwardly extending arms *18* which support an iron ring *19* having spaced coils *20*. The adjacent ends of the separate coils *20* are connected to the separate leads of the three phase alternating current circuit which sets up a magnetic field within the iron ring *19* due to the magnetic leakage. As the



current strength is progressively and uniformly changing during the current cycle there is a resultant uniform change of the direction of the magnetic field within the ring. This causes a rotary movement of the arc which prevents the concentration of the heat at a single point and permits the heat to be applied progressively. A carbon arc instead of a metallic arc may be applied with equally satisfactory results.

(Continued on page 100)

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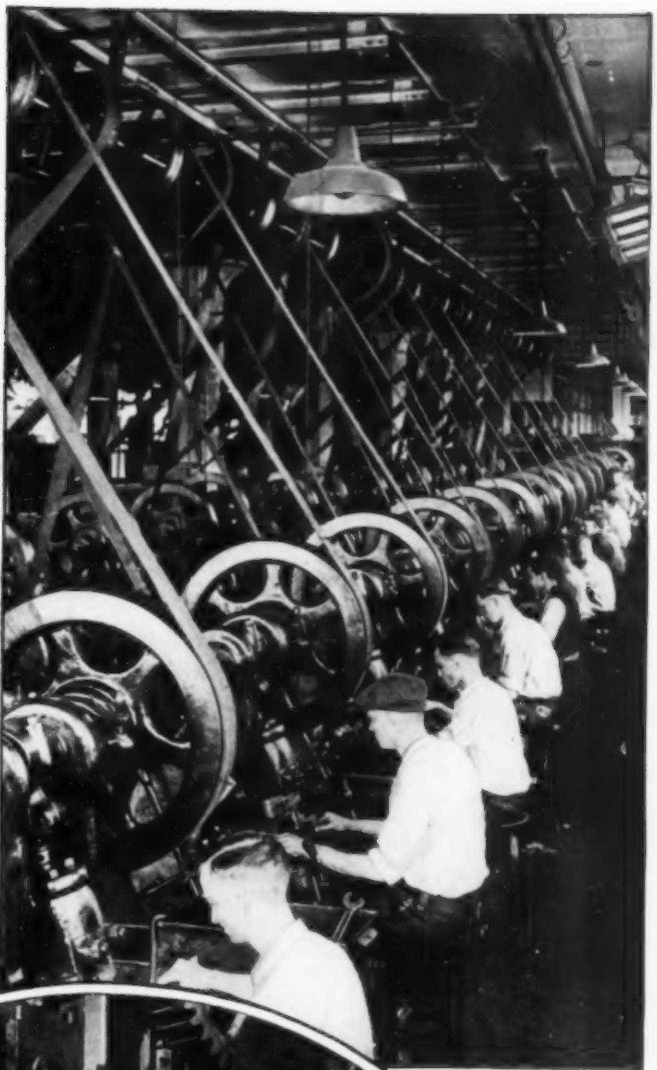

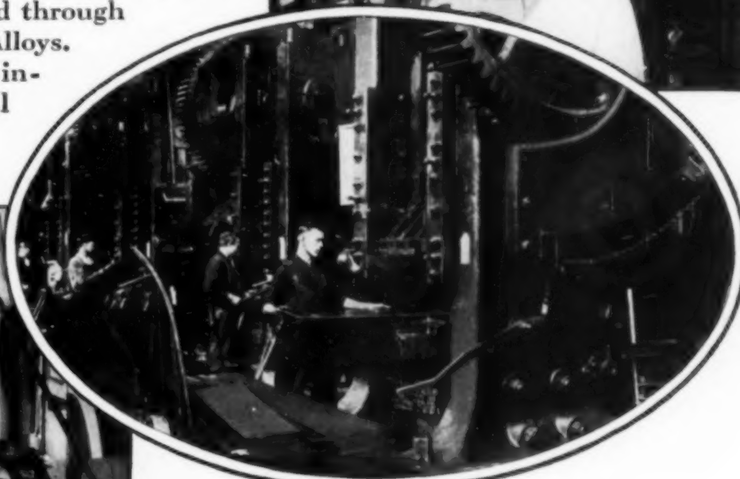

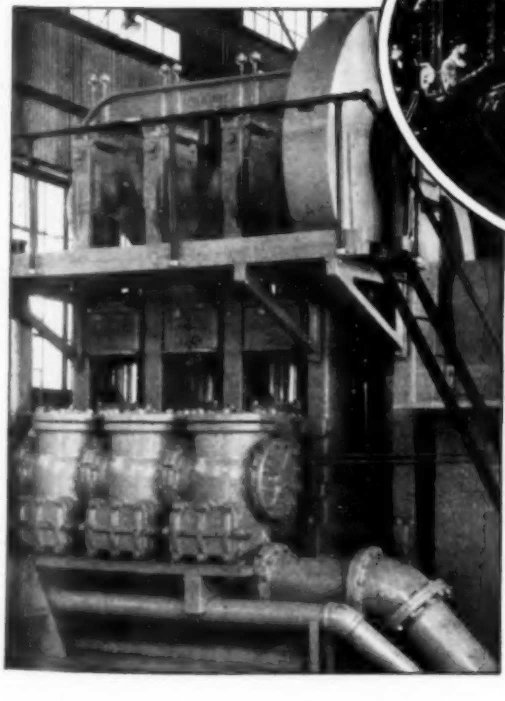

ELECTRO METALLURGICAL SALES CORP.

Unit of Union Carbide UCC *and Carbon Corporation*

Carbide and Carbon Building, 30 East 42nd Street

New York, N. Y.

Electromet

Ferro-Alloys & Metals

REVIEWS OF RECENT PATENTS

By [illegible] LITTLE

Alloying Process [illegible]

[illegible] the quality [illegible] The iron and [illegible] melting point [illegible] porous iron [illegible] completely saturated [illegible] alloy. The process [illegible] a solid uniform [illegible]

Electric Welding Apparatus [illegible] *Corp., Milwaukee* [illegible]

This invention relates to [illegible] apparatus for electric arc welding. [illegible] erals 10 and 11 indicate [illegible] the square abutting ends of [illegible] welded together. The [illegible] usual welding head which controls the [illegible] rate of the weld rod 12. Secured upon the [illegible] end of the eye piece 13 which guides the welding wire is a collar 15 having downwardly extend- [illegible]

[illegible] the heat to be applied progressively. A [illegible] instead of a metallic arc may be applied with equally satisfactory results.

(Continued on page [illegible])

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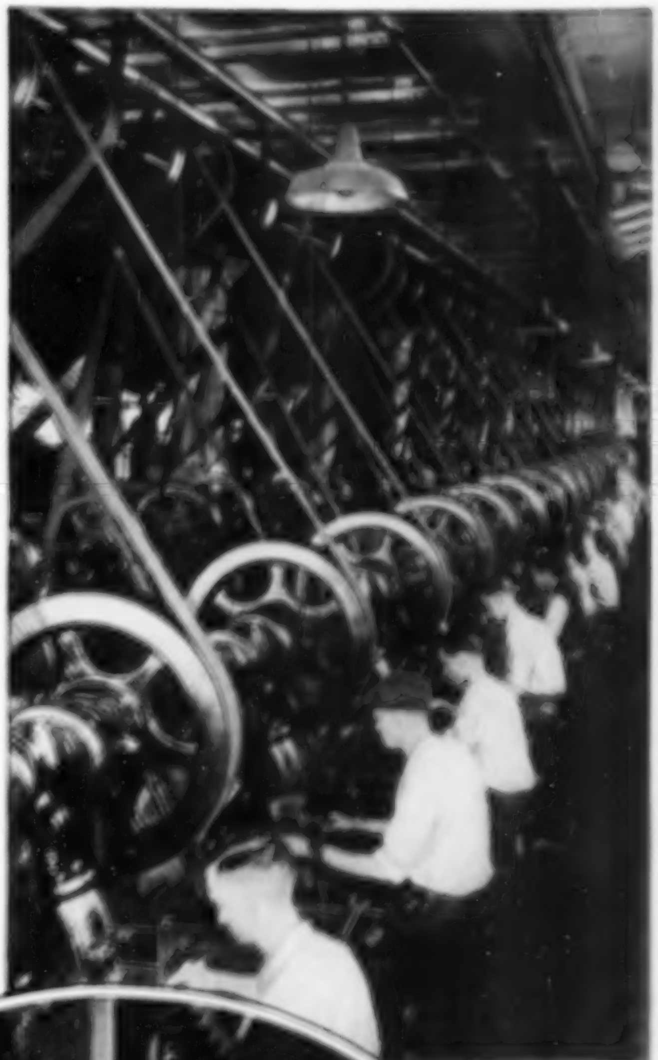

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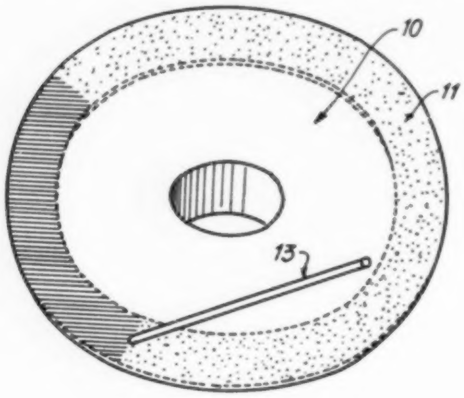
Welding Method, *by Harry J. Morgan, Walnut Park, Cal., assignor to P. L. & M. Co., Los Angeles. 1,791,168; Feb. 10.*

Under certain conditions it is desirable to secure a facing of desired uniformity and smoothness to a steel surface. In this invention powdered unwrought tungsten is mixed with a proper



amount of divided carbon with an amount of water to produce a plastic composition. Dextrine may also be added. The consistency of the composition should be such that it can be readily spread or brushed upon the surface, care being taken not to add too much water which would allow the tungsten particles to settle from the carbon. The tungsten carbide facing may contain from 3% to 10% of carbon, although 4½% is usually the maximum amount desired. When fused by an electric arc an excess of carbon must be supplied to form a neutral atmosphere preventing oxidation of the tungsten. In the figure a disk or cutter *10* is provided with a marginal portion *11* having a relatively thin layer of the plastic composition applied by means of an ordinary paint brush. After the composition has dried an arc is then struck between a carbon electrode *13* and the body of the cutter, and this arc is drawn along the marginal portion to uniformly fuse the plastic composition. Additional layers could be similarly applied and each successive layer will be harder than the preceding layer due to the presence of a smaller percentage of iron. The process covered by this patent provides a means for the deposition of a hard, wear resisting surface on a softer metal base.

(Continued on page 102)

Hard Metal Composition, *by Floyd C. Kelley, Schenectady, assignor to General Electric Co. 1,794,300; Feb. 24.*

It has been found that in order to produce the best cutting tools from powdered materials such as tungsten it is important to control the temperature of the materials during the pressing operation. In the present invention no carbon mold is employed, but rather the powdered tungsten carbon and cobalt are pressed into desired form and then sintered. Due to the temperature the tungsten carbide will adhere to the cobalt and can be readily pressed into shape in which it will retain its form. A small percentage of an alkyd resin is added to the mixture, for example, the resin made by the interaction of glycerine and phthalic anhydride. Tragacanth may also be used as a temporary binder. After the composition has been sintered it may be worked or forged at an elevated temperature such as 1375° C. and pressed between tungsten or other refractory metal blocks, the metal composition being unconfined in the lateral direction. A preferred formula consists of a composition consisting mainly of tungsten, but containing at least 3% cobalt and at least 3% uncombined carbon and a binder which is heated to the sintering temperature to form the hard tough composition.

Electric Furnace and Electric Resistance Element Therefor, *by Herbert J. McCauley, of Buffalo, New York. 1,794,310; Feb. 24.*

The object of this patent is to avoid burning out the heating element in places of localized heat in electric furnaces. The resistance elements are held flat against the lining. The resistance element is in the form of a sheet or plate of conducting material providing a zigzag path for the passage of electric current. The zigzag path permits free expansion of the element without causing an elongation, as the expansion is taken up in the slots. At the outer end the members have a cruciform opening in which the head of the bolt is engaged. Such a resistance element has an extremely long useful life due to the low watt density on the element per square inch of radiation surface.

STRUCTURAL WELDING

A design of the kind mentioned will save from 15 to 20% (or more) in the weight of the truss.

It is just as necessary to make the proper detailed shop drawings as to have the proper design. In the same manner that every dimension, rivet, and hole is fixed in a riveted member, so must every dimension and weld be fixed for the welded piece. The strength of each weld is to be figured for the stress it is to carry, and the drawing must show the length of each weld together with the size of the bead.

For economical fabrication, it is essential to have the proper shop layout, so the steel can move in a straight line from the receiving yard through the cutting, layout, punching, assembling, and welding departments, to the inspection and shipping yard.

On contracts of any size, there is some duplication of members. These can be manufactured in jigs, which expedite the assembling of the pieces. A jig may be a self-contained structure of itself, or it may be built up on the grid where the welding is done, or it may be a simple templet. The intelligent use of jigs gives a product which is accurate to dimension at a reduced cost of manufacture.

It is just as important that the welding department be furnished with the proper cranes, handling equipment, welding machines and accessories as it is that equivalent machinery be installed in any other fabrication shop. In the Austin plant portable welding machines are put in trolley cages and command the entire floor from overhead rails, independent of the hoist system. This avoids the difficulty of moving such equipment about over a floor impeded by elevated skids and steel shapes in all stages of assembly. We also use semi-automatic machines which give good results for some classes of work.

Care must be used in selecting proper operators. Just because a man has done welding for several years does not mean he is a good welder. We prefer to make our own operators. This is done by giving the man a suitable course of training which extends for several weeks. Before an operator is used for regular production work he must pass certain prescribed tests, which include test samples for bending and pulling, as given in standard specifications. At prescribed intervals, the operator is given further tests to insure that his workmanship is of the proper standard.

Careful supervision will insure good, smooth-looking welds of the proper size, dimensions, and strength. Every weld is carefully inspected to see that it is according to the drawing and is a quality weld in every way. Our own shop inspector carefully examines all the welds. Experience shows that visual inspection, supplemented in some instances by the hammer test, is all that is necessary to insure the proper strength of welds made by qualified operators.

In erecting the steel in the field, the members are placed in position in the same careful way as in a riveted structure, held in position by bolts, and the structure carefully plumbed. It is then ready for the field welding. Usually only a few machines and operators are required. Buildings of from 500 to 1,000 tons may be field welded satisfactorily by two or three operators.

As the welding progresses, each joint should be inspected by a competent inspector in the same manner as described above. For this work the services of an inspection bureau can be used to advantage.

One of the important requirements for the proper grade of welding is that the actual work be performed by a thoroughly responsible company. In this paper this has been inferred but not specifically mentioned. It will insure good work because the responsible company not only knows what is necessary to get the proper results, but will see that the successive steps and operations are actually and properly carried out. It cannot jeopardize its reputation.

To summarize: When the codes of cities and towns embrace welding, progressive architects, engineers, and construction companies consider welding on at least an equal basis with riveting, and the fabrication, erection, and inspection are performed on the bases just described, it will follow as the night follows the day that welded steel will be accepted by the owner and the public, and welded structures will rise in all sections of the country. Welding of steel will then take the place in the World's affairs it deserves.

TECHNICAL NEWS REEL

(1) Wear has little, if any, definite relationship with other mechanical properties. This is the gist of a statement made in a recent review of general wear data. Other points recognized....there can be no universal test for wear....a material for a particular service where wear is a major factor, may not be chosen on the basis of wear data alone....surface films formed may act as lubricants with some nonferrous materials, and as abrasives—iron oxide—with steel-to-steel friction....too few wear tests should not be conducted on a specimen, nor should they be too short....wear phenomena is generally regarded as due to the detachment of minute particles from the wearing surface through friction. Need of a thorough study of the subject is pointed out.

(2) Industry's annual corrosion bill in the U. S. has been stated to be a cool billion bucks. We sit up with a jerk when we're told that the oil industry's share of this loss sets us back, as individuals, no less than 1 cent on every gallon of gasoline that we buy!

(3) It will, doubtless, be reassuring to many prospective buyers of stainless culinary articles, to know that the degree of contamination of food cooked or stored in contact with chrome-nickel alloys has been declared to be negligible. Comparison with common kitchen hardware indicates the outstanding advantages and hygienic safety of chrome-nickel alloys.

(4) Painting of metal surfaces exposed to the weather should be done in the afternoon if long life is to be the result, U. R. Evans, English authority on protective coatings, tells us in a recent report. Tests have definitely proven that painting in the early morning shuts in invisible moisture films which is much more likely to cause subsequent breakdown than afternoon work after the H_2O film has evaporated. Places close to the sea are especially affected, as salt shut in under the paint has a tendency to draw in water and so causes rapid failure.

(5) In plating zinc, a nickel subcoat should be laid down as a base for subsequent protective electrodeposition. Brass, copper, silver, bronze and gold, are metals which exhibit a tendency to diffuse into the zinc, and so, of course, are unsuitable for application directly to zinc.

(6) The ability of wrought iron pipe to withstand the abrasive action to which dredge discharge lines are subjected, has been compared with the low carbon type of steel pipe commonly used for this purpose. Results indicate that the wrought iron provides approximately 65% greater service than may be secured with the steel pipe. U. S. Engineers collaborated in the investigation. The steel pipe makers are out to beat W. I. with alloys.

. . . THE METALLURGICAL INDEX

In the preparation of the Metallurgical Index by the staff of the American Society of Mechanical Engineers some 1800 domestic and foreign technical publications are regularly searched. From this material the A.S.S.T. is supplied with this selective index to those articles which deal particularly with steel treating and related subjects. Registered United States, Great Britain and Canada.

ALLOY STEEL

Some Lesser-Known Facts Concerning Alloy Steels, J. H. Andrew. *Instn. Engrs. and Shipbldrs. in Scotland—Trans.*, vol. 73, 1929-1930, pages 166-186 and (discussion) 186-198, 11 figs.

Indexed in Engineering Index 1929, p. 150, from Iron and Coal Trades Rev., Nov. 29, 1929.

Alloy Steels and Irons—Bright Spot on the Horizon, R. Tull. *Iron Age*, vol. 127, no. 6, Feb. 5, 1931, pages 449-451 and 527, 5 figs.

Essential features of principal alloy steels and their application in various industries.

The Tensile Properties of Alloy Steels at Elevated Temperatures as Determined by the "Short-Time" Method, W. Kahlbaum, R. L. Dowdell and W. A. Tucker. *U. S. Bur. Standards—Jl. of Research*, vol. 6, no. 2, Feb. 1931, pages 199-218, 18 figs.

Series of alloy steels were tested at different elevated temperatures; proportional limit was determined; materials tested were plain carbon steel and commercial alloys of chromium, vanadium, and iron with and without additions of tungsten, silicon, or aluminum, also chromium-tungsten, nickel-molybdenum and several austenitic steels; comparison of "short-time" test and "flow test" for pearlitic and austenitic steel.

Corrosion and Heat Resisting Steels, S. C. Alexander. *West. Machy. World*, vol. 22, no. 2, Feb. 1931, pages 54-56, 5 figs.

It is only through thorough consideration of inherent characteristics of various steels, method of fabrication and service conditions, that complete satisfaction will be realized in utilization of one of most outstanding developments in fields of metal in many years.

COPPER STEEL. Ueber den Korrosionswiderstand gekupferter Baustaehle (Corrosion Resistance of Structural Copper-Bearing Steels), W. Marzahn and A. Pusch. *Korrosion und Metallschutz*, vol. 7, no. 2, Feb. 1931, pages 34-39, 6 figs.

Results of corrosion tests show superiority of copper steel over structural steels without copper content, especially against action of diluted sulphuric acid and of moisture-laden air enriched with sulphurous acid; in general, results obtained in researches cited in literature have been confirmed.

ALUMINUM ALLOYS

Dimensional Stability of Heat-Treated Aluminum Alloys, J. D. Grogan and D. Clayton. *Inst. Metals—Advance Paper*, no. 553, for mtg. Mar. 11-12, 1931, 28 pages, 18 figs.

Careful search has failed to reveal occurrence of secular change in certain commercial heat-treated aluminum alloys, subsequent to completion of normal aging process; serious dimentional changes occur when machining operations are carried out on material quenched in cold water.

Untersuchung der Waermeausdehnung von Aluminum-Leichtlegierungen (Study of Thermal Expansion of Aluminum Light Alloys), H. Sieglerschmidt. *Zeit. fuer Metallkunde*, vol. 23, no. 1, Jan. 1931, pages 26-30, 7 figs.

Based on results of exact, frequently repeated expansion measurements, thermal expansion coefficients are determined for duralumin, lautal and a copper aluminum with 5 per cent copper, as well as of pure and commercial aluminum by way of comparison; special emphasis was laid on determination of influence of time.

DURALUMIN CORROSION. The Effect of Artificial Ageing Upon the Resistance of Super Duralumin to Corrosion by Sea-Water, H. L. Meissner. *Engineering*, vol. 131, no. 3401, Mar. 20, 1931, pages 406-408, and (discussion) page 384, 17 figs.

Before Inst. Metals, previously indexed from Advance Paper, no. 557, Mar. 11-12, 1931.

BEARING METALS

Bearing Metals Containing Aluminium or both Aluminium and Nickel, Nishimura. *Japanese Gov. Ry.—Bul.*, vol. 19, no. 4, Jan. 25, 1931, 43 pages, 89 figs.

Kyoto Imperial University has patented bearing alloys which contain aluminium or both aluminium and nickel, and has recommended them for use in rolling stock; comparative examination made into performance of alloys and white metals; according to results of experiment, metals are somewhat better than those containing no aluminum. (Brief abstract in English.)

Cadmium Bearing Metal, A. J. Occleshaw. *Commonwealth Engr.*, vol. 18, no. 5, Dec. 1930, pages 177-179.

Results of water-cooled, uncooled and service tests of cadmium alloy bearings; physical data relating to freezing range, Brinell hardness, casting properties, and microstructure.

BEARINGS

The Lubrication of Ball and Roller Bearings in the Steel Mill, D. E. Batesole. *Iron and Steel Engr.*, vol. 8, no. 1, Jan. 1931, pages 8-12, 10 figs.

Relative merits of oil and grease lubrication according to operating conditions and bearing designs; data on requirements for composition and properties of lubricants in relation to shaft speed; sketches illustrate sealing devices for bearings and housings.

Developments in the Design and Application of Antifriction Bearings to Rolling Mills, W. B. Moore. *Rolling Mill Jl.*, vol. 5, no. 1, Jan. 1931, pages 27-34, 10 figs.

Improvements in methods of mounting and extension that have taken place in application of tapered roller gearings to necks of new types of mills.

CASE HARDENING

Modern Casehardening Practice, F. W. Rowe. *West Scotland Iron and Steel Inst.—Jl.*, vol. 38, pt. 3, Dec. 1930, pages 27-34.

Choice of steel for case hardening; abnormality in case-hardening steels; nickel case-hardening steels; furnaces for case hardening; carburizing compounds; carburizing practice; heat treatment after carburizing; quenching media; nitrogen hardening.

Present Status of Solid Carburizers, S. P. Rockwell. *Iron Age*, vol. 127, no. 13, Mar. 26, 1931, pages 1009-1010 and 1065.

Symposium on solid, liquid and gaseous carburizers by American Society for Steel Treating; early methods of applying solid carburizers, bone and leather, and later commercial carburizers.

(Continued on page 119)

CAST IRON

The Strength of Grey Cast Iron at Elevated Temperatures, J. W. Donaldson. *West Scotland Iron and Steel Inst.—Jl.*, vol. 38, pt. 2, Nov. 1930, pages 11-17 and (discussion) 17-20, 14 figs.

Investigations to determine temperature stress curves of series of plain and alloy irons, influence of previous heat treatment on temperature stress curves, and effect of low silicon and various alloy additions on strength of cast iron at elevated temperatures both as cast and after heat treatment.

Verbesserung von Gusseisen durch Legierung und Ueberhitzung (Improvement of Cast Iron by Alloying and Superheating), E. Schuez. *Mitteilungen aus den Forschungsanstalten*, vol. 1, no. 2, Nov. 1930, pages 34-40, 4 figs. Price 2.50 m.

Metallurgical definition of cast iron; author states that iron containing less than 1.7 per cent carbon, that is, without ledeburite or graphite, or iron whose ledeburitic cementite is brought partially or wholly to disintegration through subsequent annealing, is no longer cast iron, but steel or malleable cast iron; properties of different alloys and their effects on properties of cast iron.

Etude sur les fontes au nickel-vanadium et au nickel-molybdène (Study of Nickel-Vanadium and Nickel-Molybdenum Cast Iron), J. Challansonnet. *Revue de Métallurgie*, vol. 27, no. 12, Dec. 1930, pages 654-671, 39 figs.

Physical properties, composition, crystal structure and transformation point etc. of various nickel molybdenum cast irons; data on effect of cooling velocity and dimension of molds. (Concluded.)

WELDING. Pure-Iron Electrodes for Welding Cast Iron, H. D. Lloyd and J. S. G. Primrose. *Foundry Trade Jl.*, vol. 44, no. 752, Jan. 15, 1931, pages 37-38.

Effect of phosphide eutectic; mechanical strength of welds; burning-on; thermit process; metallic-arc method; soft-iron rods; welding gas-engine bedplate; fluxes used; danger zones; welding malleable castings. Abstract of paper read before Instn. Weld-ing Engrs.

CORROSION

Die Korrosion von Eisen durch Wasserdampf bei hohen Temperaturen und ihre Physikalisch-Chemischen Grundlagen—I (Corrosion of Iron by Steam at High Temperatures and Its Physico-Chemical Principles), W. Krauss. *Korrosion und Metallschutz*, vol. 7, no. 2, Feb. 1931, pages 29-34.

Results of investigation of physico-chemical principles of iron and steel corrosion; electric measuring method for quantitative determination of reaction between metals and gases; gravimetric determinations of reaction at 600, 700, and 800 deg. cent.; comparison of values obtained by electric and gravimetric method; speed of reaction at given temperatures is determined.

Der Einfluss von hoeheren Temperaturen und Salzzusaetzen auf das Kalk-Kohlensaeure-Gleichgewicht im Wasser und die Kalk-Rost-Schutzschicht (Effect of Higher Temperatures and Salts on the Lime-Carbonic Acid Equilibrium in Water and the Lime Anti-Corrosion Layer), J. Tillmans, P. Hirsch and W. R. Heckmann. *Gas und Wasserfach*, vol. 74, no. 1, Jan. 3, 1931, pages 1-9, 4 figs.

Report from University of Frankfurt on Main; effect of sodium bicarbonate, sodium chloride, calcium chloride, calcium sulphate, and magnesium chloride on equilibrium of lime and carbonic acid at 17, 40 and 80 deg. cent.; formation of protective layer of lime; corrosion tests.

An Air-Thermostat for Corrosion Research, U. R. Evans. *Chem. and Industry*, vol. 50, no. 4, Jan. 23, 1931, pages 66-67, 4 figs.

Air thermostat erected in laboratory devoted to corrosion research in Chemical Department of Cambridge University.

Neuartige korrosionshemmende Schutzueberzuege fuer Eisen-u. Stahlwerkstueske (New Protective Coating to Prevent Corrosion of Iron and Steel), H. Reininger. *Automobiltechnische Zeit.*, vol. 34, no. 2, Jan. 20, 1931, pages 27-29.

Principles and practical procedure in application of Parkerizing, Citoxit process, and aluminum coating; microphotographs illustrate structure of protective coatings.

Versuche mit Aluminium in Soda-und Seifenloesung (Tests with Aluminium in Soda and Soap Solutions), H. Bohner. *Hauszeitschrift der V.A.W. u.d. Erftwerk A.G. fuer Aluminum*, vol. 2, no. 2, May 1930, pages 48-49.

Corrodibility of aluminum and its alloys, alone, or in presence of copper, brass, tin, zinc, iron or magnesium, by alkaline soap solutions at 20 or 50-60 deg., was measured; corrodibility is in order of potential series, but with sodium-carbonate solutions zinc is exception, having protective action on aluminum.

CUTTING TOOLS

The Machinability of Cast Iron and Cast Steel, Wallichs and Krekeler. *Foundry Trade Jl.*, vol. 44, no. 758, Feb. 26, 1931, pages 165-166, 5 figs.

Indexed in Engineering Index 1930 p. 483, from Metallurgist (supp. to Engineer, Lond.), Oct. 1930 and Archiv fuer das Eisenhuettenwesen, July 1930.

TUNGSTEN CARBIDE. Tungsten Carbide and Milling, F. H. Curtis. *Am. Mach.*, vol. 74, no. 5, Jan. 29, 1931, pages 211-213, 3 figs.

Design, operation and grinding of inserted-blade face-milling cutters, with data on feed and speed for various materials.

DEEP DRAWING

Ein neues Pruefgeraet fuel Tiefziehbleche (New Testing Apparatus for Deep-Drawn Sheets), G. Sachs. *Mitteilungen der Deutschen Materialpruefungsanstalten*, no. 8, 1930, pages 80-85, 7 figs.

Deficiencies of present testing methods and devices; apparatus developed is in form of drawing nozzle and method is termed wedge drawing test; it is claimed to be superior to deep drawing test for exact determination of drawability.

ELECTRIC FURNACES

Recent Trends in Electric Heating, G. M. Bayne. *Elec. News*, vol. 40, no. 3, Feb. 1, 1931, pages 79-80, 1 fig.

New types of highly efficient electric furnaces available for specific requirements indicate that application of electric heat-treating is only in its infancy.

Les progrès récents de l'emploi du four électrique en aciérie (Recent Progress in Application of Electric Furnaces in Steel Plants), A. Levasseur. *Arts et Métiers*, no. 125, Feb. 1931, pages 54-60.

Relative merits of principal types of electric furnaces in refining of steel and production of special steels and alloys.

Montreal Plant Produces Electric Furnace Steel in Large Quantities. *Can. Machy.*, vol. 42, no. 5, Mar. 5, 1931, pages 27-30, 5 figs.; see also *Iron and Steel Canada*, vol. 14, no. 2, Feb. 1931, pages 30-32, 3 figs.

Canadian Tube and Steel Products, Ltd., Montreal, has become independent for their steel ingot and rod requirements through installation of electric steel-melting furnaces; installation consists of two Volta furnaces of Heroult type; electrode arrangements; furnace tilting; oxidation and reduction; low voltage use; ingot stripping.

Electric Furnaces and Low-Temperature Treatments, J. E. Oram. *Metallurgia*, vol. 3, no. 15, Jan. 1931, pages 94-96, 5 figs.

Low-temperature heat-treatments offer additional scope to electric furnace; low operating and maintenance costs and ease of temperature control are associated with this type of equipment.

REFRACTORY MATERIALS. Refractory Materials for Electric Furnaces, A. B. Searle. *Metal Industry (Lond.)*, vol. 38, no. 1, Jan. 2, 1931, pages 3-4.

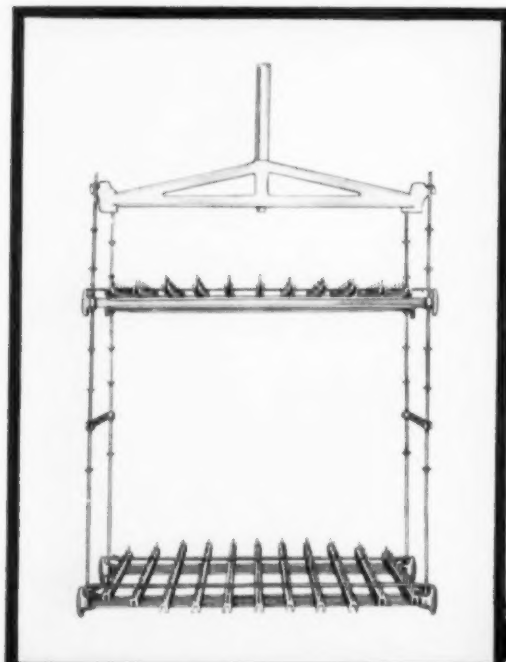
Melting of lead and its alloys including type of metal, babbitt metal, and solder; temperature considerations; types of brick; shapes of bricks for lining; furnace roof.

ELECTRIC WELDING

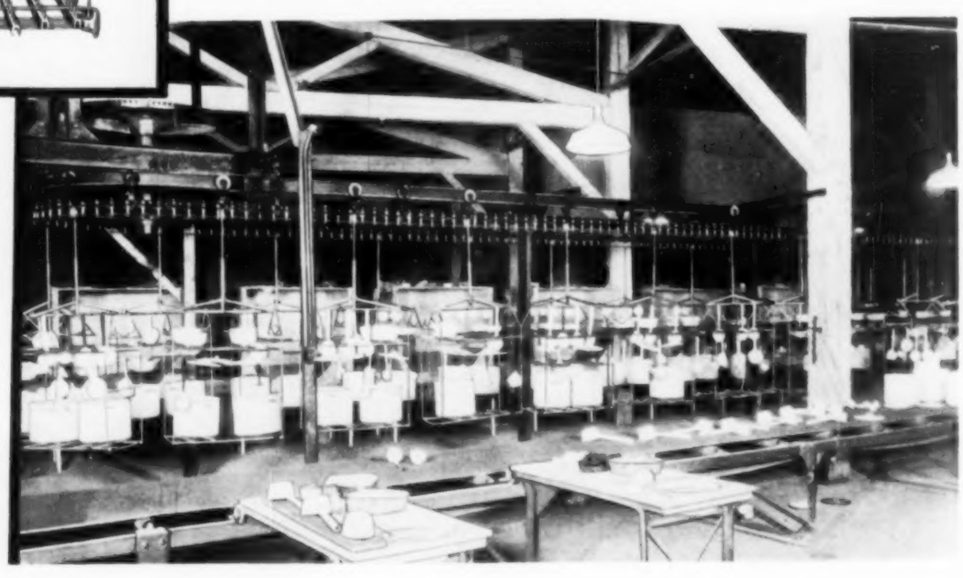
Arc Welding in 1931, J. F. Lincoln. *West. Machy. World*, vol. 22, no. 2, Feb. 1931, pages 65-66.

Every year since war use of arc welding has gained greater momentum in practically every industry; regardless of economic outlook for 1931, it is safe to say that this process will be applied more widely and more frequently than in any preceding year; development of electrodes during past year for welding of various steel alloys will bring about much wider applications of arc welding and in turn permit wider use of these alloy metals.

(Continued on page 126)



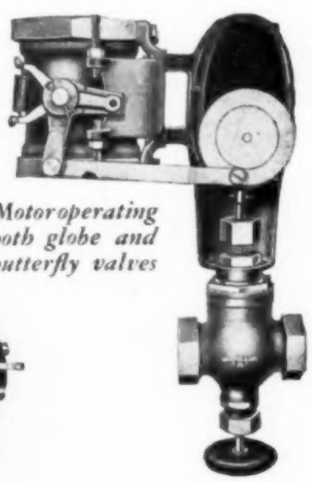
Close-up of CALITE Enameling Rack.



Does an inspector

1000 MILES AWAY

know you need AUTOMATIC CONTROL?



Motor operating both globe and butterfly valves

Type V-30 gas valves for low pressure gas

Temperature controller

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DEFORMATION. Zur Deutung der Deformationstexturen von Metallen (Deformation Textures of Metals), W. Boas and E. Schmid. *Zeit. fuer Technische Physik*, vol. 12, no. 2, 1931, pages 71-75, 4 figs.

Tests made at Kaiser-Wilhelm Institut fuer Metallforschung on nature of strains produced by tensile, upsetting and rolling stresses.

On the Plasticity of Metals, Z. Jeffries. *Mech. Eng.*, vol. 53, no. 4, Apr. 1931, pages 262, 266, 2 figs.

High plasticity largely responsible for widespread use of industrial metals; most favorable arrangement of atoms for slip movement; small loads required to permanently deform single crystals; possibility that free electrons are essential for metallic plasticity.

FAILURES. Diagnosis of an Interesting Mechanical Failure, G. Sproule. *Can. Foundryman*, vol. 22, no. 2, Feb. 1931, pages 10-13, 10 figs.

General discussion on failures; case of failure of tapered pinion seat of motor armature shaft is analyzed.

HEAT OF FORMATION. A Further Investigation of the Heat of Mixture in Molten Metals, M. Kawakami. *Tohoku Imperial Univ. —Science Reports*, vol. 19, no. 5, Dec. 1930, pages 521-549, 27 figs.

Heat of mixture for 25 systems of binary alloys which contain as one component, magnesium, antimony, aluminum, silver, copper or gold; values obtained by calculation from either volume change with van Laar-Lorenze's equation or electromotive force measured by N. Taylor agree fairly; theoretical formula for solid solution from solid components derived from thermodynamics, by means of which heat of formation for several alloys is found to be endothermic.

INCLUSIONS. Untersuchungen ueber den Einfluss von Sauerstoff und Schwefel auf die Schmiedbarkeit, Rotbruechigkeit und andere Eigenschaften des reinen Eisens (Study of Influence of Oxygen and Sulphur on Malleability, Red Shortness and other Properties of Pure Iron), E. W. Fell. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 8, Feb. 1931, pages 393-400, 8 figs.

Alloys with varying oxygen and sulphur content were produced, using as base a metal as free as possible from usual impurities in ingot steel electrolytic or Armco iron); gas determination; impact tests; Brinell hardness.

NITRIDATION

Un bel exemple de collaboration de la science et de l'industrie: l'utilisation des oscillations de haute fréquence en métallurgie (Utilization of High Frequency Oscillations in Metallurgy), Fayollet. *Aciers Spéciaux Metaux et Alliages*, vol. 6, no. 65, Jan. 1931, pages 11-15, 1 fig.

Applications and possibilities of high-frequency oscillation in improving physical properties of alloy steels, with particular regard to nitridation with simultaneous high frequency treatments.

(Continued on page 140)

NON-FERROUS METALS

BRASS. Der Einfluss von dritten Metallen auf die Konstitution der Messinglegierungen (Influence of Third Metal on Constitution of Brass Alloys), O. Bauer and M. Hansen. *Zeit. fuer Metallkunde*, vol. 23, no. 1, Jan. 1931, pages 19-22, 24 figs.

Influence of tin; contribution to problem of ternary system tin-zinc-copper; photomicrographs of structure; this is conclusion of series of articles on study of ternary brass alloys and contains summary of results obtained and report on determinations of Brinell hardness.

Press Working and Forming of Metals—The Hot Press Forging of Brass, E. V. Crane. *Metal Stampings*, vol. 4, no. 1, Jan. 1931, pages 39-42, and 72, 5 figs.

Chemical composition of brass for forging; common practice in producing brass press forgings.

COPPER FOUNDING. Ueber Temperaturmessungen an fluessigem Kupfer und seinen Legierungen (Temperature Measurements of Molten Copper and Its Alloys), H. Miething and C. Winkler. *Giesserei*, vol. 18, no. 9, Feb. 27, 1931, pages 181-184.

Temperature measurements were carried out in non-metallic foundry with Holborn-Kurlbaum pyrometer on following molten metals: copper, phosphorous bronze, bronze B, cast bronze, different bearing bronzes, and also on brass.

OPEN HEARTH FURNACES

The Design and Operation of Open Hearth Furnaces, C. E. Veach. *Rolling Mill Jl.*, vol. 5, no. 1, Jan. 1931, pages 15-18.

History of open-hearth furnace, and discussion of open-hearth campaign. (To be continued.)

Clean Steels; from Acid Open-Hearth, C. H. Herty, Jr. and J. E. Jacobs. *Metal Progress*, vol. 19, no. 2, Feb. 1931, pages 93-99, 6 figs.

Study by United States Bureau of Mines and Heppenstall Co. of Pittsburgh, on elimination of nonmetallic matter originating in charge and from furnace lining, oxidation of metal during working of heat, deoxidation with ferrosilicon and ferro-manganese and with special manganese-silicon alloys, elimination of silicates in ladle for two grades of alloy steel.

OXYACETYLENE WELDING

Hochdurck- und Niederdruck-acetylen im Schweissbetriebe (Welding Operations with Pressure and Low Pressure Acetylene), E. Zorn. *Autogene Metallbearbeitung*, vol. 24, no. 3, Feb. 1, 1931, pages 35-43, 16 figs.

Operation and design of injectorless welding equipment, including types of torch, valve, and acteylene compressors, etc.; data on effect of flame on properties of weld; advantages of high-pressure acetylene welding regarding uniformity of quality. (Concluded.)

Einfluss der Azetylendruecke auf die Guete der Schweissnaht (Effect of Acetylene Gas Pressure Upon Qualities of Welded Joints), K. Gabler. *V.D.I. Zeit.*, vol. 75, no. 3, Jan. 17, 1931, pages 77-81.

Report on original experiments for determination of most favorable pressure, taking into account gas consumption, and mechanical and metallurgical properties of welds.

PICKLING

Pickling—Efficient Plant Practice, F. McC. Burt. *Ceramic Indutry*, vol. 16, no. 3, Mar. 1931, pages 276-279, 1 fig.

Early pickling practices; modern pickling operations. (To be continued.)

PYROMETERS

Pyrometers, A. N. Lindberg. *Factory and Indus. Mgmt.*, vol. 81, no. 2, Feb. 1931, page 252, 2 figs.

Rules governing use of recording pyrometers; installing pyrometers in heat-treating plants.

SHEET STEEL

Zur Pruefung der Oberflaechenbeschaffenheit von Blechen (Testing of Surface Properties of Plates), E. Gerold. *Stahl und Eisen*, vol. 51, no. 4, Jan. 22, 1931, pages 104-106, 5 figs.

Results of tests to determine roughness of plate surfaces with Kempf-Fluegge polarization smoothness tester made by Schmidt & Haensch, and with Askania smoothness tester; these and also an arrangement with photoelectric cell, can be successfully applied, but they are not recommended for acceptance testing.

Making Corrosion-Resisting Sheets With Polished Surface, T. H. Gerken. *Iron Age*, vol. 127, no. 6, Feb. 5, 1931, pages 456-460 and 527, 6 figs.

Production methods and equipment in rolling and finishing steel sheets in Park works of Crucible Steel Co. of America mill for making corrosion resisting sheets is served by rotary-hearth furnaces for both pack heating and normalizing; sketch illustrates floor plan.

STEEL

COLD WORKING. The Cold Finishing of Steel Bars, J. R. Miller. *Heat Treating and Forging*, vol. 17, no. 1, Jan. 1931, pages 40-43 and 49, 3 figs.

Methods for manufacture of cold rolled and cold drawn bars; sketches illustrate groove for cold rolling rolls and die for drawing round bars; built up die for squares and flats; cost data for various operations in manufacturing process.

FATIGUE. Beitrag zur Frage der Schwingungsfestigkeit (Contribution to Problem of Torsional Strength), W. Schneider. *Stahl und Eisen*, vol. 51, no. 10, Mar. 5, 1931, pages 285-292, 12 figs.

Importance of endurance properties for designer; endurance tests and short-time methods; bearing on tensile strength and yield limit; influence of different surface conditions; investigations of alloy and unalloyed steels of different strength.

STAINLESS. Making Rustless Steel in Open Hearth or Electric Furnaces. *Iron Age*, vol. 127, no. 6, Feb. 5, 1931, pages 466-469.

Metallurgical aspects of both methods with particular regard to fabrication and heat treatment based on German experience; table gives data on compositions of most common chrome and chrome-nickel steels; composition charges for production of chrome steel and austenitic chrome-nickel steels in basic open hearth furnace.

STRUCTURAL. Ueber die Verteilung der Festigkeitseigenschaften in gewalzten Stahlprofilen (Strength Properties of Rolled Steel Sections), F. Sauerwald. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 9, Mar. 1931, pages 431-434, 5 figs.

Possible causes of differences in strength of rolled sections; methods of distinguishing between these properties; effect of segregations and irregular deformation; influence of annealing; hardness distribution in round bars and its change due to cold working.

STEEL ANALYSIS

Correct Methods of Analyzing for Carbon in Rustless Steels, C. M. Johnson. *Iron Age*, vol. 127, No. 7, Feb. 12, 1931, pages 549-561.

Methods for obtaining accurate analyses of both low and high-sulphur types according to practice of Crucible Steel Co.

Discontinuities. *Metallurgist (Supp. to Engineer)*, Feb. 27, 1931, pages 18-19.

It is difficult to deal with discontinuities, more or less internal, and therefore hidden, which occur in steel in form of non-metallic enclosures; it should be direct aim of engineers to secure, and of metallurgists to produce, steel as free from these injurious features as possible; now that importance of these internal defects has been more fully recognized it may be easier to identify them by microscopic examination and time may not be far distant when some test of cleanness of steel may be introduced into specifications.

Das Verhalten der Begleitelemente des Eisens, besonders des Sauerstoffes bei der Seigerung des Stahles, mit Beitragen ueber die Seigerung in Stahlbloecken (Behavior of Accompanying Elements of Iron, Especially Oxygen, in Segregation of Steel), P. Bardenheuer and C. A. Mueller. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 9, Mar. 1931, pages 411-419, 17 figs.

Segregation of iron impurities in non-silicated steels with low and high carbon content; segregation of oxygen in steel; significance of results for segregation of steel; origin of ingot segregation and effect of gas formation on solidification; segregation in ingots; influence of oxygen content on steel-ingot segregation.

Quick Method for Determining Sulphur in Steel, P. V. Sakharov and F. N. Ribinsky. *Vestnik Ingenieurov i Technikov*, no. 6, June 1930, pages 223-227, 9 figs.

Principles of sulphur determination in steel; outline of standardized procedure based on Bauman method. (In Russian.)

STATEMENT OF OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.,

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High Speed Steel Furnaces—C. I. Hayes, Inc. Booklet describing the Hayes "Certain-Curtain" electric furnace for the heat treatment of tools. Description of how scaling and pitting are reduced by the control of the furnace atmosphere. Bulletin M-43.

Steel Users Reference Book—William Jessop & Sons, Inc., issue a booklet showing compositions, thermal treatment, mechanical properties and uses of various types of tool and constructional steels. The theories of hardening are discussed in their practical aspects. Bulletin M-61.

Pot Type Furnaces—Hevi Duty Electric Co. A description of the standard pot type furnaces used for the immersion method of heat treating parts. Illustrations, along with the specifications, are also given. Bulletin M-44.

Industrial Application of the X-Ray—Booklet gives many examples of the use of the X-ray in the industrial field. Profusely illustrated with radiographs of castings, welds, assemblies, etc. Bulletin M-6.

Fabrication of Allegheny Metal—Allegheny Steel Co. Booklet of interesting information on the fabrication of this chromium-iron alloy. Bulletin M-20.

Carbidefree Alloys—Metal and Thermit Corp. A booklet describing their metals and alloys as produced by the aluminothermic process. Bulletin M-64.

Acid Resisting Baskets—Weaver Brothers Co. Circular describing and illustrating a wide variety of acid resisting baskets covering many industrial applications. Bulletin M-52.

Furnaces—George J. Hagan Co., industrial furnace builders, have recently issued several new descriptive booklets describing their furnaces. Copies are available by requesting bulletin M-42.

Practical Metallurgy for Engineers—E. F. Houghton & Co., Philadelphia. A 435-page book by the Houghton Research Staff, covering practical metallurgy in all its phases. Copies of the third edition are obtainable by sending $3.00 directly to the above company.

Conveyor Belts—Wickwire Spencer Steel Co. A new portfolio describing the salient features of all types of Wissco conveyor belts, including the new heavy duty Atlas link belt for conveying heavy bulky materials through continuous heat treating operations. Bulletin M-37.

Nitriding Furnaces—American Electric Furnace Co., will be glad to send their new bulletin which covers their new Nitro furnace for nitriding. Bulletin M-2.

Grinding and Polishing Machine—E. Leitz, Inc. New single spindle device with automatic arrangement for polishing, representing improvement over all previous constructions is listed in a new pamphlet. Bulletin M-47.

Carburizing Compound—Char Products Co. booklet describing process of manufacture and performance of Char carburizing compounds and offering the advantages of a carburizing material which does not burn on exposure to air. Booklet M-58.

Automatic Process Control—Brown Instrument Co. 48-page booklet on automatic controls for temperatures, pressures, flows, liquid levels and other process operating factors. Shows how temperature controls can be applied to all types of furnaces, kilns, ovens, kettles, etc. Bulletin M-3.

Cyanides—The Roessler and Hasslacher Chemical Co., Inc. Folder illustrating simplified apparatus and method of controlling cyanide baths for heat treatment and case hardening of carbon and alloy steels. Directions for use, etc., are included. Bulletin M-29.

Corrosion-Resisting Steel—Bethlehem Steel Co. Booklet fully describing Bethalon, a corrosion resisting steel that combines immunity to corrosion with the easy machinability of screw stock. Bulletin M-76.

Forge Furnaces—W. S. Rockwell Co. Booklet describing and illustrating forging furnaces of the economizer shield type. These forges are designed for the use of oil or gas and low pressure air. M-49.

Gas Burners—American Gas Furnace Co. Bulletin illustrating and describing burners used for local hardening and tempering of hack saw blades, wrenches, chisels, screw drivers, punches, pliers, etc. They are also used for soldering and brazing steel parts in laboratories and repair shops. Bulletin M-11.

Alloy Products—The Pressed Steel Co. in their new catalog give interesting data relative to Rezistal Lite-Wate carburizing and annealing containers and other equipment. Bulletin M-67.

Welding Inspection and Test—Westinghouse Electric & Mfg. Co. A 16-page booklet featuring the methods of arc welding inspection and test used by this company. This includes testing of oil-tight and air-tight tanks. One of a series of bulletins published for users of arc welding. Bulletin M-53.

Pictorial Panorama of Progress—International Nickel Co. A series of folders illustrating and describing typical commercial applications of structural nickel alloy steel as an engineering material in machinery and equipment parts. (4 pages each). Bulletin M-45.

Pyrometers—Charles Engelhard, Inc. The subjects of sensitivity, resistance, support and control of moving coil, and temperature coefficient are discussed in a bulletin describing features of indicating and recording pyrometers. Bulletin M-14.

Fatigue Testing Machine—Thompson Grinder Co. Interesting data on fatigue testing and a description of the rotating beam type of fatigue testing machine are given in bulletin M-23.

Steel Journal and Stock List—Joseph T. Ryerson & Son, Inc. 128-page booklet giving stock sizes, weights, extras, etc. on all alloys and general steel lines carried in stock. It also contains 32 pages of trade news, articles on business con-

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Refractories—The Carborundum Co. Reference data pamphlet covering physical and chemical characteristics of super-refractory brick, tile, special shapes and cements of Silicon Carbide and electrically fused aluminum oxide types. Bulletin M-57.

Furnaces—Surface Combustion Corporation invites your request for new bulletins M-51A on Continuous Annealing Furnaces; M-51B on Carburizing, Annealing and Hardening Furnaces; M-51C on Muffle Type Hardening Furnaces.

Industrial Regulators—Minneapolis-Honeywell Regulator Co. Booklet describing their motorized valves used in furnace temperature regulation. These valves operate with their regulators or with any pyrometric controller to regulate flow of gas, oil and air. Bulletin M-48.

Resistance Thermometers—Leeds and Northrup Co. Revised catalog treating in detail resistance thermometers for recording, controlling and indicating temperatures, covering heating and ventilating, applications in refrigeration and chemical plants, gas-making and other low temperature applications. Bulletin M-46.

Induction Furnaces—Ajax Electrothermic Corp. This bulletin gives latest information regarding coreless induction furnaces in capacities up to several tons, and motor-generator equipments for energizing the furnaces. Bulletin M-41.

Scale Prevention—Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Bulletin M-36.

Tool Steel Handbook—Columbia Tool Steel Co. Description and correct use of tool steels. Hints on how to avoid hardening failures. Also, heat treating methods and valuable information tables. Booklet M-28.

Heat Treating Information—Chicago Flexible Shaft Co., has available copies of the "Stewart Melting Pot." This booklet gives definitions and descriptions of various heat treating operations, charts, etc. Bulletin H-1.

Blast Gates—Ryan, Scully & Co. Newly issued blast gate bulletin describing butterfly type gates said to offer improved controlled operation over the sliding plate gate for controlling air and gas at normal and excess temperatures. Bulletin H-4.

Tungsten Carbide Tools—Firth-Sterling Steel Co. Booklet and catalog on Firthite tungsten carbide, describing applications, methods of grinding, etc. Typical examples are given of this material in comparison with other tools on various production jobs. Bulletin H-5.

Heat Resisting Alloy—Ohio Steel Foundry Co. Photographs of typical applications of Fahrite Heat Resisting Alloy are given in this 20-page bulletin. Bulletin H-7.

Handbook of Alloy Steels—Republic Steel Corp. Agathon Alloy Steels Handbook is available in a revised edition. Complete instructions for the heat treatment of the various steels are given in chart form for easy reading. Bulletin H-8.

Resistant Alloys—Calorizing Co. A technical bulletin giving physical properties of nickel-chromium-iron alloys at operating temperatures. These alloys are adapted to various applications where heat and corrosion are encountered. Photographs of typical applications are given. Bulletin H-9.

Gas Heat—American Gas Association. A new booklet on the application of gas heat to a wide variety of industrial processes. Bulletin H-10.

Alloys for High Temperature—Michigan Steel Casting Co. Alloy castings and fabricated products for use at high temperatures are illustrated and described in a 16-page bulletin. Bulletin H-12.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin H-13.

Heat Treat Supplies—Case Hardening Service Co. Supplies and equipment for the modern heat treating plant are described in a 24-page catalog. Numerous illustrations and many helpful suggestions for economical heat treating and equipment operation are given. Bulletin H-15.

Ferro Alloys—Electro Metallurgical Sales Corp. Ferro Alloys and Metals are fully described in the third edition of this catalog. The products furnished by this company to the various metallurgical industries are also included. Bulletin H-16.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin H-17.

Heat Resisting Alloys—Driver-Harris Co. A number of interesting Nichrome installations are illustrated in a brochure covering the applications of this heat resisting alloy. Bulletin H-19.

Tool Steels—Carpenter Steel Co. "Timbre and How It Affects the Properties of Carbon Tool Steel" has been published by the research department. Timbre is defined and illustrated and means of testing for it are given. Bulletin H-26.

Hy-Ten Steel—Wheelock, Lovejoy and Co. Hy-Ten steels suitable for every vital machine part, coming in carbon contents from .10 to 1.00 per cent, are described in a valuable booklet on this steel. Bulletin H-22.

Fatigue Testing Machine—Thompson Grinder Co. Interesting data on fatigue testing and a description of the rotating beam type of fatigue testing machine are given in Bulletin H-23.

Resistance Wire—Hoskins Mfg. Co. Technical information and data on thermocouple alloys, chromel resistance wire and other resistance alloys are given in a new catalog and handbook. Bulletin H-24.

Furnace Heating Elements—Globar Corp. Physical characteristics and applications of Globar heating elements are given in a bulletin, "Globar Non-Metallic Electric Heating Elements." Bulletin H-25.

Chrome Ore—E. J. Lavino & Co. Literature on the use of plastic K-N chrome ore for making furnace hearths, insuring a smooth, hard working surface and giving long service life. In addition these hearths heat stock faster, produce cleaner work and reduce maintenance costs. Bulletin H-40.

Deoxidizers—Vanadium Corp. of America. Alsifer, a material used for the deoxidation of steel during manufacture, is described in a new leaflet. Bulletin H-27.

Corrosion and Heat Resisting Steels—Colonial Steel Co., Vanadium Alloys Steel Co., and Anchor Drawn Steel Co. Booklet intended for shop men to whom it gives valuable technical information and complete data regarding the following various types of stainless steels: A, B, I, FMS, N, U, CNC. Bulletin H-28.

Fuel Fired Furnaces—Electric Furnace Co. Oil and gas fired continuous and batch type billet heating, forging and car-type furnaces are illustrated in a bulletin on furnaces for heating, normalizing and heat treating, also describes labor saving material handling equipment. Bulletin H-30.

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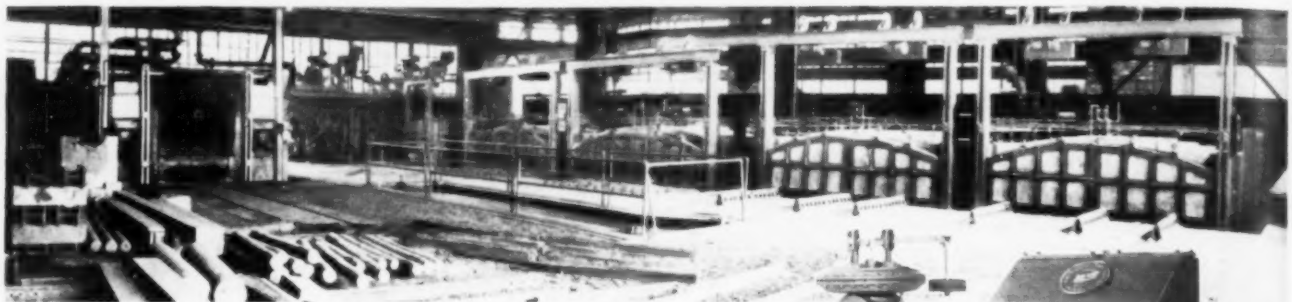

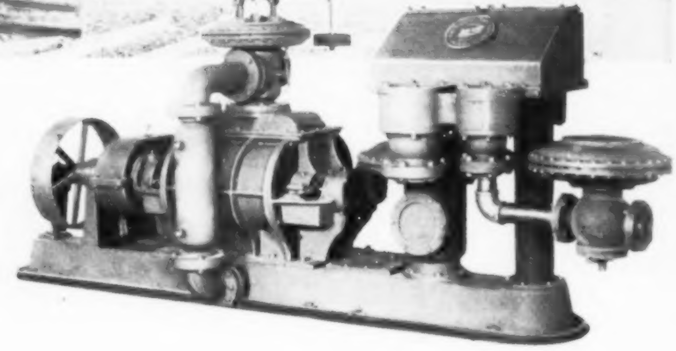

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